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Did a falling meteor kick-start Christianity?

NewScientist

WEEKLY April 25 - May 1, 2015

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HOW WE SEE REALITY

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Technological cures for political impotence

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drive bees mad

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A vote for change

It will take people, as well as technology, to fix the political system

POLITICS is broken. Across the globe, voter turnout has been in decline for decades. The electorate believes that “the parties are all the same, the politicians are all the same, they are not like us, it does not make any difference”, according to Ruth Fox, director of the Hansard Society, which records British political discourse.

Low turnout breeds further discontent. It is impossible to construct an electoral system that is perfectly fair (1 May 2010, p 28), but low turnout exacerbates the sense of unfairness when a minority government is elected, or when tiny factions end up tipping the balance of power.

Technocrats have long hoped that social media might empower the public – helping them to make their voices heard. But what has transpired has been not so much a transformation of politics as more of the same. Sloganeering, hucksterism and gaffes persist: the abiding impression is often of ever bigger megaphones blaring in an ever bigger echo chamber.

We should spare a thought for the politicians, too. Consider this: they are now open all hours to their constituents’ every whim and whinge, their every utterance recorded and pored over by their opponents. Is it any wonder they struggle to engage?

So what is to be done? It is not that people have lost interest in issues such as health, education, welfare or homes. “Even the most disengaged... including people who had never voted, could not be described as not caring,” reported the Speaker’s Commission on Digital Democracy in January. But they no longer feel connected to politics as they once did, as card-

“We have the beginnings of a solution. Online campaigns are easy to sign up to and can attract huge support”

carrying members of a party or trade union, for example.

We have the beginnings of a solution. Online campaigns are easy to join, and can thus quickly attract huge support – but are all too easily ignored. So hacktivist groups are now building tools that buttress their efforts with real ballot-box power, helping people deploy their votes effectively and liberating policymaking from the wonks and lobbyists (see page 38).

These tools are gaining ground, both in austerity-stricken states where conventional politics has fallen furthest from grace, and in progressive democracies. In some, such as Spain, their adoption may have been helped by memories of more dictatorial forms of rule.

The new systems are distinctly rough and ready. Some require us to reconsider such sacred cows as the secret ballot; they may prove vulnerable to manipulation and mob rule. But dismissing them because they don’t yet have all the answers would be a mistake, just as it was a mistake to sneer at the call from comedian Russell Brand to opt out of the current system. Brand clearly struck a chord with the young and discontented, even if he proposed no real alternative.

Better to harness that energy to find that alternative. There is a precedent. In the wake of the 2008 financial crisis, many economics students protested against courses dominated by unrealistic models. A radically revamped curriculum is now being tried out at institutions around the world. Pillars of the Establishment, notably the Bank of England, are rethinking economics too (28 March 2015, p 28).

We don’t want to wait for a crisis of democracy to prompt a rethink of politics. Nor should we wait for politicians to act: that would be like turkeys voting for Thanksgiving. If the task is to return power to the people, it has to start with the people too. Ever fewer of us may want to engage with the current political system. But we should all engage with the task of fixing it. ■



Protesting vaccine rules

Waiting for Mars

DREAMS of a Mars landing may have to wait. No one is going there any time soon, according to leading space-agency figures on both sides of the Atlantic. Despite plans to land on the Red Planet

“Children who watched the first moon landing will be nearly 100 before they see a repeat on Mars”

from companies like SpaceX and Mars One, both the current head of NASA and the incoming head of the European Space Agency (ESA) say we'll be waiting decades for humans to walk on Martian soil.

“No commercial company without the support of NASA and government is going to get to Mars,” NASA administrator Charles Bolden told a hearing of the US House Committee on Science, Space and Technology in mid-April.

But NASA itself doesn't have a firm date for landing – its loose and unfunded plan is for humans to touch down on Mars in the 2030s. The agency is planning to train for

a deep-space mission by first visiting a small boulder plucked off a larger asteroid around 2025.

Johann-Dietrich Wörner, who is head of German space agency DLR and will become ESA director-general in July, thinks even these goals are ambitious. He told German newspaper *Der Spiegel* that it would be “very demanding” to land on Mars before 2050 because of the difficulties of health, psychology and launching from Mars. If he's right, children who watched the first moon landing in 1969 will be nearly 100 before they see a repeat on Mars.

JONATHAN CARRUTHERS



Drawn to the bad stuff?

Hard line on vaccination

THE Disneyland measles outbreak was declared over on Friday, but the death threats and Nazi references are still circulating.

The outbreak, which began at the Californian park in December, has seen 147 people from seven states contract the virus. Of the 81 Californians whose vaccination status is known, 70 per cent were unvaccinated. As *New Scientist* went to press, Californian senators were due to vote on a bill designed to prevent parents exempting their kids from standard school vaccinations on the grounds of “personal belief” rather than genuine medical reasons.

The bill has proved highly contentious, with vociferous protests from the anti-vaccination lobby, a Facebook post portraying the

senator who co-wrote the bill as a Nazi and threatening emails sent to the authors' offices.

The US isn't the only country struggling with its vaccination rates. The Disneyland outbreak is dwarfed by an ongoing measles epidemic in Germany. As of Monday, there have been 1738 cases reported, quadruple the total number for 2014. The outbreak has led to calls for mandatory measles vaccinations.

In Australia, the government announced a “no jab, no pay” policy last week that will mean withholding welfare payments from parents who fail to have their children immunised. It follows the death of a 4-week-old baby last month from whooping cough, who was too young to be vaccinated against the disease.

Greener Australia

AUSTRALIA has a chance to forge ahead with renewable energy. The country could get 100 per cent of its electricity this way by 2050 with very little impact on the economy, says a report commissioned by conservation organisation the WWF. It could also produce zero net emissions by 2050 at a cost of as little as 0.1 or 0.2 per cent of GDP, especially by making significant changes in its supply chain and use of energy.

“Australia is unusually well placed in that the technical

potential for renewable energy is practically unlimited,” says the report's author, Frank Jotzo of the Australian National University in Canberra.

But instead, the government is planning to lower Australia's current renewable energy target of 41,000 gigawatt hours by 2020, and has been ripping up its climate-change mitigation measures since a change of government in 2013. “Other countries are aware of the political shift that has gone on in Australia and take a very dim view of it,” says Jotzo.

Bees' predicament

HOW would you like your sugar? If you're a bee, the answer seems to be “with a dash of pesticide”.

This is the latest twist in the tale of neonicotinoid pesticides and their disputed effects on bee health. Given a choice, honeybees and a species of bumblebee had a preference for sugar solutions with neonicotinoids (*Nature*, DOI: 10.1038/nature14414). This might result in bees getting much higher doses of these pesticides than we

had realised, says Dave Goulson of the University of Sussex, UK.

Other findings published this week suggest that neonicotinoids have a harmful short-term impact on wild bees. At sites treated with the substances, there was a drop in wild bee density, solitary bee nesting and bumblebee reproduction, compared with control plots, although there was no effect on honeybees (*Nature*, DOI: 10.1038/nature14420). "Whether this also translates into long-term population consequences is still an open question," says Maj Rundlöf of Lund University in Sweden.

Vaping rules

THE smoke of choice for US schoolkids has changed. In 2014, for the first time, more high-school students smoked electronic cigarettes than traditional ones. Whether the rise of e-cigarettes is welcome news or a fresh face on an old public-health menace is not yet clear.

Although the number of teenagers admitting they smoke any kind of tobacco product hasn't drastically changed since 2011, the number of high schoolers smoking e-cigarettes leaped from 1.5 per cent in 2011 to 13.4 per cent in 2014.

If the 22,000 youngsters polled for the National Youth Tobacco Survey are representative of their peers nationwide, this equates to 2.4 million students vaping last year, triple the number in 2013. Using a hookah was also twice as popular in 2014 than 2013.

The survey showed cigarette smoking was down from 15.8 per cent in 2011 to 9.8 per cent in 2014.

A similar study carried out in Wales, UK, suggests that vaping does not have the same foothold on the other side of the Atlantic. Researchers at Cardiff University found that e-cigarette use is only catching up with traditional tobacco use in younger teenagers, with those aged 15 and 16 still preferring cigarettes.

Click to vote

CALL it a success for clicktivism. A new online voter registration system for the upcoming UK election has smashed all records, with over 450,000 people signing up to vote the day before the 20 April deadline.

Previously, voters could only register by filling out a paper form, which some feared was off-putting, particularly for young people who may never have voted before. Figures suggest as many as 7.5 million eligible voters were not registered. "As people increasingly grow to expect that

they can conduct almost every aspect of their lives online, it is time electoral registration caught up," said government minister Greg Clark at the launch of the system last year.

The online system only requires a few clicks, along with your national insurance number or other ID for authentication. Politicians, columnists and celebrities have been driving people to register on Twitter and other social media, with great success. Over a million signed up in the last week of registration; just 55,000 paper sign-ups occurred in the same time period.

FBI confesses to hair mistakes

SOMETIMES you win or lose by a whisker. The FBI has admitted that flawed evidence was accepted in nearly all of the trials in the 1980s and 1990s that included microscopic hair analysis evidence.

Since 2012, the FBI has been reviewing 2600 cases in which hair evidence was among that used to secure a conviction. The trials under scrutiny took place between about 1980 and 1999, when hairs were assessed by microscope - a technique criticised for its lack of rigour.

Of the 268 trials reviewed so far, more than 95 per cent included evidence that was overstated by analysts. Death sentences were given in at least 35 of those cases, and nine people were executed.

Another five died in prison. The trials are likely to have involved other evidence, though.

Written reports on hair analysis were often sound and framed with caveats, but evidence tended to be exaggerated in court, says Peter De Forest, a forensic consultant in New York. "Very often the testimony went way beyond the report," he says.

In a statement, the FBI said that it now uses mitochondrial DNA hair analysis. But even this can only distinguish individuals from different maternal lines, so wouldn't be able to tell the difference between anyone related on their mother's side. And many jurisdictions don't use it because it is expensive and time-consuming, said the FBI.



Bad hair day

60 SECONDS

You smell like lunch

Irresistible to mosquitoes? Thank your genes. Identical twins are similarly attractive to mosquitoes - much more so than non-identical twins. This suggests genes contribute to the body odours that attract and repel the insects (*PLoS One*, DOI: 10.1371/journal.pone.0122716).

Japan moon shot

Japan's space agency plans to send its first uncrewed probe to the moon in 2018 or 2019, reports *The Japan Times*. The mission is a follow-up to its 2007 orbiter, which was smashed into the moon in 2009. The mission could pave the way for sending people to the moon - something only the US has done so far.

Sensitive souls

Ouch. The brains of newborn babies appear to respond to pain in a similar way to those of adults. Researchers poked the feet of adults and babies less than a week old while they were in an MRI scanner. They found that 18 of the 20 brain regions active in adults experiencing pain also lit up in the babies. The infants also appeared to have a lower pain threshold (*eLife*, doi.org/3vB).

Our cannibal past

Cannibalism might have been a custom for our Stone-Age ancestors, who even carved the leftover skulls into cups for use in mortuary rituals. Extensive evidence of butchering and human tooth marks were found on bones from Gough's Cave in Cheddar Gorge, Somerset, UK, that are almost 15,000 years old (*Journal of Human Evolution*, doi.org/3vc).

Bunny trouble

Climate change will affect two-thirds of lagomorphs, the order that rabbits and hares belong to. Many will be forced to more northern habitats or higher altitudes. Pikas will see their mountain habitats shrink and some may even go extinct as a result (*PLoS One*, doi.org/3t9).

Christianity's meteoric rise

Did a first-century fireball help a small sect become a world faith?

Jacob Aron

NEARLY two thousand years ago, a man named Saul had an experience that changed his life, and possibly yours as well. According to Acts of the Apostles, the fifth book of the biblical New Testament, Saul was on the road to Damascus, Syria, when he saw a bright light in the sky, was blinded and heard the voice of Jesus. Changing his name to Paul, he became a major figure in the spread of Christianity.

William Hartmann, co-founder of the Planetary Science Institute in Tucson, Arizona, has a different explanation for what happened to Paul. He says the biblical descriptions of Paul's experience closely match accounts of the fireball meteor seen above Chelyabinsk, Russia, in 2013.

Hartmann has detailed his argument in the journal *Meteoritics & Planetary Science* (doi.org/3vn). He analyses three accounts of Paul's journey, thought to have taken place around AD 35. The first is a third-person description of the event, thought to be the work of one of Jesus's disciples, Luke. The other two quote what Paul is said to have subsequently told others.

"Everything they are describing in those three accounts in the book of Acts are exactly the sequence you see with a fireball," Hartmann says. "If that first-century document had been anything other than part of the Bible, that would have been a straightforward story."

But the Bible is not just any ancient text. Paul's Damascus conversion and subsequent missionary journeys around the Mediterranean helped build Christianity into the religion it is today. If his conversion was



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The biblical prequel to Chelyabinsk

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indeed as Hartmann explains it, then a random space rock has played a major role in determining the course of history (see “Christianity minus Paul”, below).

That’s not as strange as it sounds. A large asteroid impact helped kill off the dinosaurs, paving the way for mammals to dominate the Earth. So why couldn’t a meteor influence the evolution of our beliefs?

“It’s well recorded that extraterrestrial impacts have helped to shape the evolution of life on this planet,” says Bill Cooke, head of NASA’s Meteoroid Environment Office in Huntsville, Alabama. “If it was a Chelyabinsk fireball that was responsible for Paul’s conversion, then obviously that had a great impact on the growth of Christianity.”

Hartmann’s argument is possible now because of the quality of observations of the Chelyabinsk incident. The 2013 meteor is the most well-documented example of larger impacts that occur perhaps only once in 100 years. Before 2013, the 1908 blast in Tunguska, also in Russia, was the best example, but it left just a scattering of seismic data, millions of flattened trees and some eyewitness accounts. With Chelyabinsk, there is a clear scientific argument to be made, says Hartmann. “We have observational data that match what we see in this first-century account.”

The most obvious similarity is the bright light in the sky, “brighter than the sun, shining round me”, according to Paul. That’s in line with video from Chelyabinsk showing a light, estimated to be around three times as bright as the sun, that created quickly moving shadows as it streaked across the sky.

After witnessing the light, Paul and his companions fell to the ground. Hartmann says they may have been knocked over when the meteor exploded in the sky and generated a shock wave. At Chelyabinsk, the shock wave

destroyed thousands of windows and knocked people off their feet.

Paul then heard the voice of Jesus asking why Paul, an anti-Christian zealot to begin with, was persecuting him. The three biblical accounts differ over whether his companions also heard this voice, or a meaningless noise. Chelyabinsk produced a thunderous, explosive sound.

Paul was also blinded, with one account blaming the brightness of the light. A few days later, “something like scales fell from his eye and he regained his sight”. Our common idiom for suddenly understanding something stems from this description, but Hartmann says the phrase can be read literally. He suggests that Paul was suffering from photokeratitis, a temporary blindness caused by intense ultraviolet radiation.

“It’s basically a bit of sunburn on the cornea of the eye. Once that begins to heal, it flakes off,” says Hartmann. “This can be a perfectly literal statement for someone in the first century who doesn’t really understand what’s happening.” The UV radiation at Chelyabinsk was strong enough to cause sunburn, skin peeling and temporary blindness.

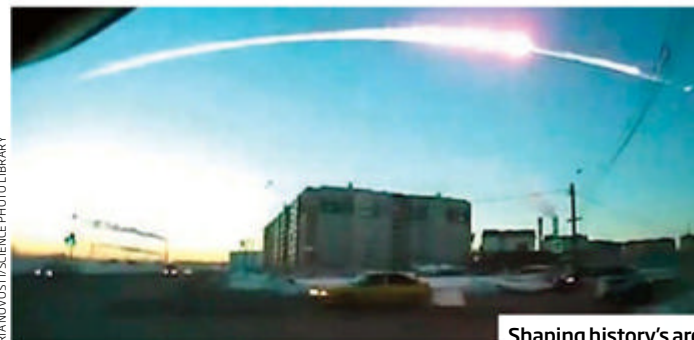
Raj Das-Bhaumik of Moorfields

CHRISTIANITY MINUS PAUL

IF A falling meteor did inspire Paul’s conversion to Christianity (see main story), that makes a random event hugely important in the history of humanity. What if Paul hadn’t seen the fireball?

“Some scholars call Paul the second founder of Christianity,” says Justin Meggitt, a religious historian at the University of Cambridge. At the time, Christianity was a small offshoot of Judaism, but Paul helped preach a version of it that broke with Jewish law.

Paul wasn’t the only first-century missionary, and without him Christianity would probably still have separated from Judaism and spread



RIA NOVOSTI/SCIENCE PHOTO LIBRARY

Shaping history’s arc

Eye Hospital in London says the condition is common among welders whose eyes are exposed to bright sparks, but the symptoms aren’t exactly as Hartmann is suggesting. “You wouldn’t expect bits of the eye to fall off; I’ve not come across that at all,” he says.

“If a large asteroid impact helped kill the dinosaurs, why couldn’t one influence the evolution of beliefs?”

It’s possible that the thin skin of the eyelids could burn and peel off, he says, but that is unlikely to happen in isolation. “If this were a meteorite, I’m sure you’d have other damage as well.”

Mark Bailey of Armagh Observatory in the UK, who previously identified a Tunguska-like event in Brazil in the 1930s,

around the world, says Meggitt. But Paul’s teachings have endured through the ages, and their absence would be felt.

“People’s interpretation of Paul is absolutely fundamental to some of the central figures of Christianity,” says Meggitt. For example, Martin Luther, who started the Protestant Reformation in 1517, was heavily inspired by Paul’s letters.

Specific predictions about how Christianity and world events would have unfolded without Paul’s influence are hard to make, says Meggitt, but “Christianity probably would be very different without him”.

says it’s worth analysing old texts for clues to ancient impacts – bearing in mind that accounts are shaped by what people knew at the time. “Sometimes that doesn’t make sense to us, but it does make sense if you can reinterpret it.” What does he think of Hartmann’s argument? “He does a very detailed analysis,” says Bailey.

“I would label it as informed speculation – Bill Hartmann is an excellent author,” says Cooke. “But like so many other things in the ancient past there is no real concrete evidence, no smoking gun.” And with no other accounts from the time to draw on, there is little additional evidence to confirm or disprove the idea.

A search for meteorites in and around Syria could prove fruitful – Chelyabinsk left small chunks all over the region – but even that would be inconclusive. “If a meteorite is discovered in modern Syria in the future, the first thing to test would be how long it’s been on the Earth and whether it could potentially be associated with such a recent fall,” says Bailey. But even with our best techniques, dating such a rock to the nearest hundred years would be difficult.

Even so, Hartmann believes we need to think seriously about the implications of his idea. “My goal is not to discredit anything that anybody wants to believe in,” he says. “But if the spread of a major religion was motivated by misunderstanding a fireball, that’s something we human beings ought to understand about ourselves.” ■

Ancient virus is embryo protector

Andy Coghlan

WE MAY owe our survival and complexity to a stowaway virus that springs to life in the very first cells of human embryos. Not only does the virus seem to protect embryos from other viruses, it also assists genes as they build the body plan of a new human.

The finding supports the controversial idea that viruses that took up residence in our DNA millions of years ago may be playing the role of puppet master, quietly influencing our existence and evolution. “We are creatures controlled by viruses,” says Luis

“Stowaway viruses may be playing puppet-master, quietly influencing our existence and evolution”

Villarreal of the University of California, Irvine.

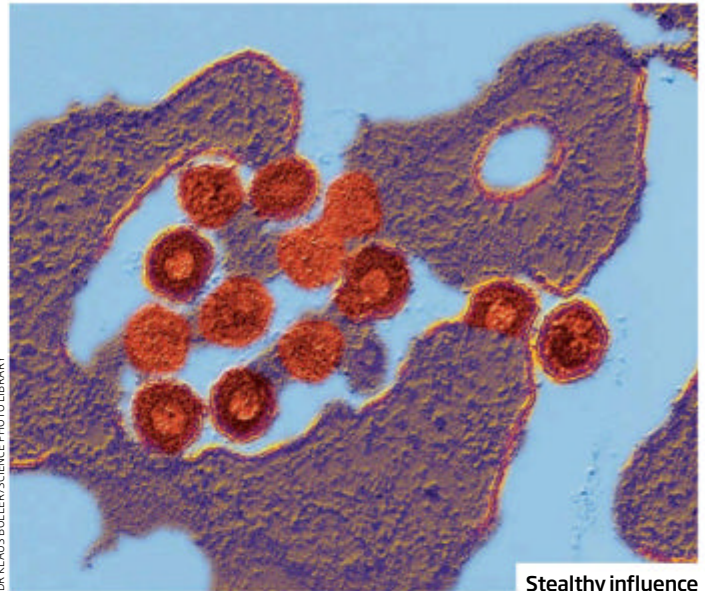
Most viruses infect us by injecting their genetic material into our cells. Retroviruses go one step further and insert it directly into our DNA. At first, this causes disease and death, but over thousands of years of repeated infection, resistance to the virus evolves, allowing any viral DNA that has embedded itself into

sperm or egg cells to be passed on to the next generation. The virus is now said to be “endogenised” – it has become a permanent fixture in the genome.

About 9 per cent of the human genome is thought to have come about this way. Until recently, these viral relics were largely dismissed as inactive “junk” that ceased to have any impact many thousands of years ago. The discovery that the most recent retrovirus to make itself at home in our DNA – probably around 200,000 years ago – is active in human embryos challenges that notion.

Joanna Wysocka and her colleagues at Stanford University in California made the unexpected find while they were analysing gene activity in 3-day-old human embryos, which are bundles of eight cells. Besides signs of parental DNA, they found that genetic material from the virus HERV-K was active too. “The cells were full of viral protein products, some of which had assembled to form viral-like particles,” says Wysocka.

Further experiments revealed that HERV-K appears to produce a protein that prevents other viruses penetrating the embryo, suggesting it protects it from



DR KLAUS BOLLER/SCIENCE PHOTO LIBRARY

Stealthy influence

circulating viruses such as influenza. It also seems to play a crucial role in the genetic activity of the embryonic cells, helping to ferry genetic instructions to the cellular protein factories (*Nature*, doi.org/3wh).

Tantalisingly, the stowaway virus might even provide clues to what makes us different from chimps and other non-human primates. Some researchers have argued that endogenised retroviruses may be key to how species diverge from each other, by activating different body plans and gene networks that may give one individual an edge over other members of the species.

Wysocka's work backs up this idea, says Patrick Forterre of the

Pasteur Institute in Paris. “It shows that the protein products of a relatively ‘recent’ retrovirus integration are present very early on in the embryo, and could be involved in some critical developmental programmes.” The observation that retroviruses could also protect the embryo against infection makes a lot of sense too, says Forterre. “It’s as if retroviruses are competing with each other via their human host.”

Despite being ubiquitous, viruses are often called the dark matter of biology as their influence frequently goes unnoticed. If DNA is a jungle, then the viruses are the animals and plants that live and adapt within it, says Villarreal, who in 2001 showed that the presence of a viral gene is essential for the formation of the human placenta.

The most influential viruses are those that have inserted themselves permanently into our DNA, says Villarreal. These have the genetic tools to refashion the hosts' genes, influencing which are active and when, and with which other genes they interact. This means they have the ability to reshape the physical characteristics of their hosts, he says. “It’s a massive dynamic pool of colonising genomes.” ■



SUZIESZTERHAS/MINDEN PICTURES/REPA

Pass it on

KOALA TAKE-OVER

Viruses that embed themselves in our DNA may be shaping our existence and evolution much more than we give them credit for (see main story).

But it's not just humans that viruses like to get cosy with. The process of viral DNA embedding itself into a host's genome is known as endogenisation and is happening right now in koalas.

Koala retrovirus, or KoRV,

appeared about 100 years ago and probably originated as a mouse virus. It has since spread through 75 per cent of the animals' range, triggering leukaemia in the marsupials. Survivors retain KoRV DNA in their sperm and eggs, transmitting the virus to future generations without causing disease. “This is true endogenisation, and we’re seeing this in real time,” says Luis Villarreal at the University of California, Irvine.

Under pressure in the operating room

I WAS prepared for the blood but the most shocking thing about watching brain surgery was seeing the surgical drapes being stapled to the patient's face. But surgeon Peter Hutchinson dismisses my concern that the tiny holes might bother the patient when she wakes up: "That's nothing compared with the massive hole we're about to make in her head."

I am at Addenbrooke's Hospital in Cambridge, UK, to learn about craniectomy, a procedure that involves removing a large part of someone's skull, to relieve the pressure inside. There are no official tallies but it's thought that several hundred surgeries take place in the UK every year on people with head injuries or who have had a stroke. Once the brain is given room to swell, the pressure drops and the scalp is sewn back into place. The skull fragment can be stored in a freezer or kept sterile inside the patient's abdomen for weeks or months before it is reattached.

The operation I'm witnessing is part of a randomised trial to compare the effectiveness of craniectomy with that of drugs alone to bring the pressure down. It will involve 400 people with

head injuries, half of whom will get the surgery.

This is needed as craniectomy has a long and chequered history. Human remains suggest it was done with stone tools in Peru a thousand years ago, a practise known as trepanning, perhaps for similar reasons as today. As a modern surgical procedure, though, it has fallen in and out of

favour over the last few decades. Whether you would be sent for surgery today depends on how safe your surgeon thinks it is.

There are concerns that while it may save people's lives, it might make it more likely that someone will end up in a vegetative state. The number of people in this state is rising in most Western countries, as more people survive serious injuries thanks to medical advances. But some are concerned that craniectomy is contributing.

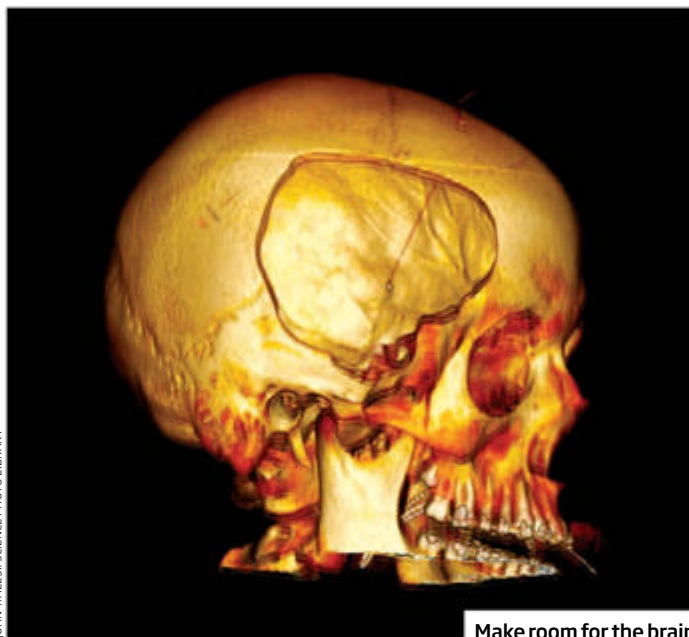
The problem with the procedure is that such a brutal

assault could be doing more harm than good. One risk is infection, caused by bacteria on the patient's skin entering the wound. Hence the need to anchor the drapes so firmly in place to ensure the skin stays covered up.

Another risk is nicking a major blood vessel. I see how this fear affects the surgical team when I observe a second operation. The patient needs a circle of skull removed that overlies a major artery. The team members joke about how, if things go wrong, they will need to change their socks – because of the ensuing torrent of blood. The banter stops as they start to ease the skull away from the brain, gently severing recalcitrant tissue. With the skull removed, they step back to look at the blood vessel almost reverently, then delicately cover it with gauze.

The man's brain throbs before our eyes with each beat of his heart. Hurt it, and he could awake unable to speak or move – or he might not wake at all.

Hutchinson has spent years planning this trial and convincing colleagues at other hospitals to take part. But he insists he doesn't care what the outcome is, merely that we finally learn if we should use this controversial procedure. "I'm not passionate about the operation, I'm passionate about the trial," he says. "We need answers." **Clare Wilson ■**



JOHN T. ALES/SCIENCE PHOTO LIBRARY

Make room for the brain

CO₂ could make a giant battery underground

WHAT if we transformed carbon dioxide from being a waste product into being a huge battery to help even out our energy supply? We could make carbon storage pay off, while solving problems of intermittent energy supply from renewables.

So say Tom Buscheck from the Lawrence Livermore National Laboratory in California and his colleagues, who presented a design

for this type of energy storage at the European Geosciences Union general assembly last week in Vienna, Austria.

The design stores excess grid energy in two ways: pressure and heat. First, CO₂ in a supercritical state – a hybrid between liquid and gas – is pumped into brine in sedimentary rocks between 1 and 5 kilometres below the surface. Second, more of the energy is used to heat the brine that is displaced by this, before it is sent back down. The heated brine causes the CO₂ to expand and increases its pressure. To release the stored energy, the CO₂ is depressurised and spins

supercritical CO₂ turbines, which are 50 per cent more efficient than the steam equivalent. The team's models suggest the system could regather up to 96 per cent of the stored heat.

A site employing the system could store about 8 million tonnes of CO₂ each year for 30 years – the amount a large coal-fired power station produces, says Buscheck, whose group is looking for power companies to partner with on a pilot project.

"A site employing the system could store about 8 million tonnes of CO₂ each year for 30 years"

Carbon capture and storage has been slow to develop, in part because it is an extra cost for energy producers that provides little direct pay-off. "No one has come up with a viable use for that storage," says Buscheck. "The only way you can decarbonise the fossil-fuel energy systems is if you can devise an approach where the economics makes sense."

Whether it is possible to scale up the design remains to be seen, says Jim Underschultz from the University of Queensland in Australia. Given its complexity, he says that costs and inefficiencies could add up. Michael Slezak ■

Proto-quantum computer boosted

Jacob Aron

QUANTUM computers should in theory outpace ordinary ones, but attempts to build a speedy quantum machine have so far come up short. Now an approach based on a Victorian counting device seems to be getting close.

This proto-quantum computer can only solve one problem. But that problem, called boson sampling, is difficult for an ordinary computer to solve, so physicists hope that such a device will conclusively demonstrate the promise of computing based on exotic physics. "The goal is to show quantum supremacy with the simplest approach," says Fabio Sciarrino of Sapienza University of Rome, Italy, who helped develop the new machine.

Boson samplers are based on a device created by 19th-century polymath Francis Galton to study statistical distributions. Balls are dropped one by one from the top of a wooden board studded with pegs and ping their way down, bouncing left or right at each peg before collecting in bins at the bottom. Because balls are more likely to end up in a central bin than one at the edges, you end up with a bell-shaped distribution

curve across the width of the board. In the pre-computer age, it was one of the best ways to compute this distribution, which often crops up in statistics.

The quantum version swaps balls for photons, which travel along a network of intersecting channels in an optical chip. When two photons collide, their ensuing paths are determined by the laws of quantum mechanics, producing a unique distribution. With enough photons, calculating this distribution becomes difficult on an ordinary computer, so doing it

"Perhaps the first boson sampler will one day sit alongside Babbage's difference engine"

with real photons in a quantum device is the only practical option.

In 2012, four research groups, including Sciarrino's, demonstrated the first working boson samplers with three photons. But scaling up to larger numbers was challenging because it is difficult to produce single photons on demand.

Sciarrino has therefore turned to a slightly different version of the problem, called scattershot boson sampling. This involves using a

larger number of photon sources, so that their randomly generated photons have a higher chance of colliding. His team used six sources and were able to produce three photons at once, making the new boson sampler 4.5 times as fast as the 2012 ones, on average (*Science Advances*, doi.org/3vj).

Now his team is working to improve its sources even further, with the aim of challenging an ordinary computer.

Scott Aaronson of the Massachusetts Institute of Technology, who helped come up with the idea of boson sampling, thinks the device is an important milestone, but not yet a breakthrough. "Hopefully, they will have better scaling going forward," he says. "Twenty or 30 photons would be spectacular."

The skills and technology needed to get a boson sampler working with more photons should help enable more general-purpose quantum computers in the future, says Aaronson.

Even if it can't factor large numbers or perform other quantum tricks, a device that unambiguously demonstrates quantum supremacy would be a major scientific breakthrough. Perhaps the first record-beating boson sampler will one day sit in a museum alongside Charles Babbage's difference engine, the mechanical precursor to modern computers. "I like that image," Aaronson says. "I'd go visit it in a museum." ■

Shrunken snails offer a glimpse of the future

IT'S the survival of the smallest.

As ocean acidification begins to bite, some marine species might adapt by shrinking - threatening the profitability of commercial fisheries. The phenomenon is known as the "Lilliput effect", after the fictional island inhabited by tiny people in *Gulliver's Travels* by Jonathan Swift.

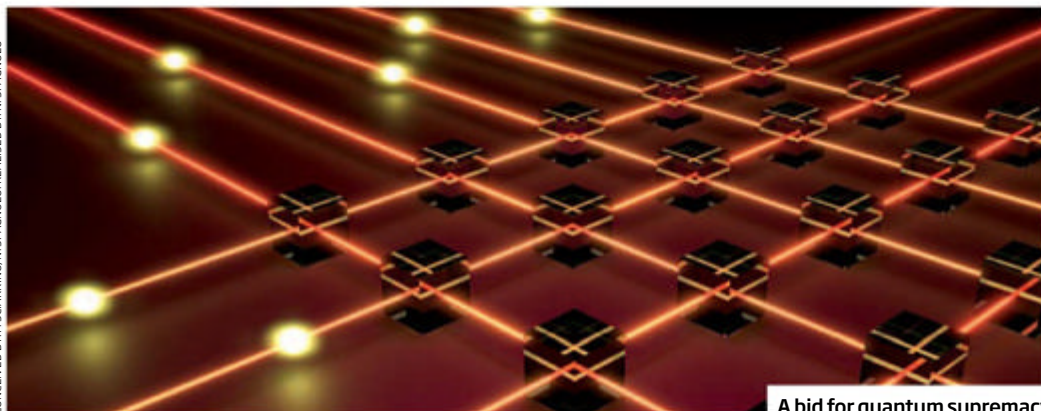
Over time, carbon dioxide emitted into the atmosphere dissolves in the ocean, causing it to become more acidic. At times in Earth's distant past this has triggered mass extinctions that wiped out most species. Many marine shellfish, corals and fish that made it through the turmoil shrank by one-third or more, and remained small for tens of thousands of years, says Richard Twitchett at the Natural History Museum in London.

Now it seems that the Lilliput effect is poised to return, as a direct result of present-day ocean acidification.

Twitchett, working with Jason Hall-Spencer at Plymouth University, UK, and his team, studied marine communities living around volcanic seeps in the Mediterranean Sea. The seeps naturally inject CO₂ into the seawater, making it more acidic than usual. They found that there was a 30 per cent drop in biodiversity near the volcanic vents, and members of two species of sea snail that do live there are about 1.5 times smaller than members of the species living beyond the influence of the seeps (*Nature Climate Change*, doi.org/3vk). In other words, the vent snails are Lilliputians.

"The smaller organisms can survive high CO₂ concentrations because they don't need as much oxygen," says Hall-Spencer, whose team revealed this in subsequent lab tests.

If marine shellfish in general begin to adapt to lower pH conditions by shrinking, there could be commercial implications for people who make a living from growing shellfish. "You're not going to make much money if everything shrinks," says Hall-Spencer. Colin Barras ■



A bid for quantum supremacy

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FIELD NOTES Ontario, Canada

Ready, steady, go find dark matter

Louisa Field

I FEEL a rush in my stomach as the cage drops and the pressure on my eardrums increases. I am travelling 2 kilometres underground in a metal box that will carry me to the front line in the search for dark matter. I am eager to see DEAP, the world's most sensitive detector before it is sealed off forever – but right now I wish I could stay at sea level.

My guide, Jack Dunger from the University of Oxford, reassures me. “The cage is much scarier than the tunnel,” he says. “Once you are down there you will feel more normal.”

The stuff Dunger's colleagues are so keen to find is anything but normal. Dark matter accounts for about 80 per cent of the universe's matter, yet only makes itself felt through gravity. It keeps galaxies from flying apart, but has never appeared in a detector.

DEAP, the Dark matter Experiment using Argon Pulse-shape discrimination, is based on the theory that dark matter is a weakly interacting massive particle. These antisocial WIMPs are difficult to detect because they are, as the name suggests, unwilling to play with other particles. However, physicists hope that the interactions are just rare, rather than non-existent.

To help shield the detector from cosmic rays, which can mimic WIMPs, DEAP is located in the Sudbury Neutrino Observatory (SNOLAB), 2 kilometres beneath the frozen Canadian wasteland in the deepest area of an active nickel mine. At the end of April, it will join other underground detectors worldwide in the race to find dark matter.

Dunger leads me through a maze of white sterile corridors that suddenly open up into a massive cavern. In front of me is DEAP itself – a huge ball, 3.4 metres across, hanging from the ceiling by its steel neck. Here, I meet Mark Kos and Peter Skensved of Queens University, Canada, and ask them why they think DEAP could succeed where its competitors have failed.

“The short flippant answer is that we built a better detector,” Skensved grins.

“DEAP has two things really going for it. First of all, it's very large,” Kos adds. “When it starts

running it will be the biggest dark matter detector in the world.”

DEAP can hold more than 3 tonnes of liquid argon, although they expect only the innermost part of the chamber to record a collision between a WIMP and an argon nucleus. Such an interaction would make the nucleus recoil, sending out a tiny flash of light. Photodetectors surrounding the argon will pick up this flash and reveal the presence and properties of the WIMP that caused it.

“The more mass you have the higher the chance is that dark matter will interact in your detector, so this goes towards increasing the sensitivity,” Kos says. The second advantage is the detector's depth and shielding, which protect it from background radioactivity in the surrounding materials, including the cavern

rock. Because it is so far underground, SNOLAB provides 100 times as much shielding from the muons in cosmic rays as the lab at Gran Sasso in Italy. This is home to similar dark matter experiments such as XENON1T, which will start number-crunching in the autumn.

“Muons are problematic because they can break up nuclei, releasing neutrons, and neutrons

“When it starts running at the end of April, DEAP will be the biggest dark matter detector in the world”

look just like WIMPs when they interact in dark matter detectors,” Kos says.

The dearth of WIMP strikes in other experiments like XENON and the LUX detector in South Dakota has worried physicists. But those detectors are more sensitive to low-mass WIMPs, while DEAP will have world-leading sensitivity to the higher-mass WIMPs that some theories favour, Kos says.

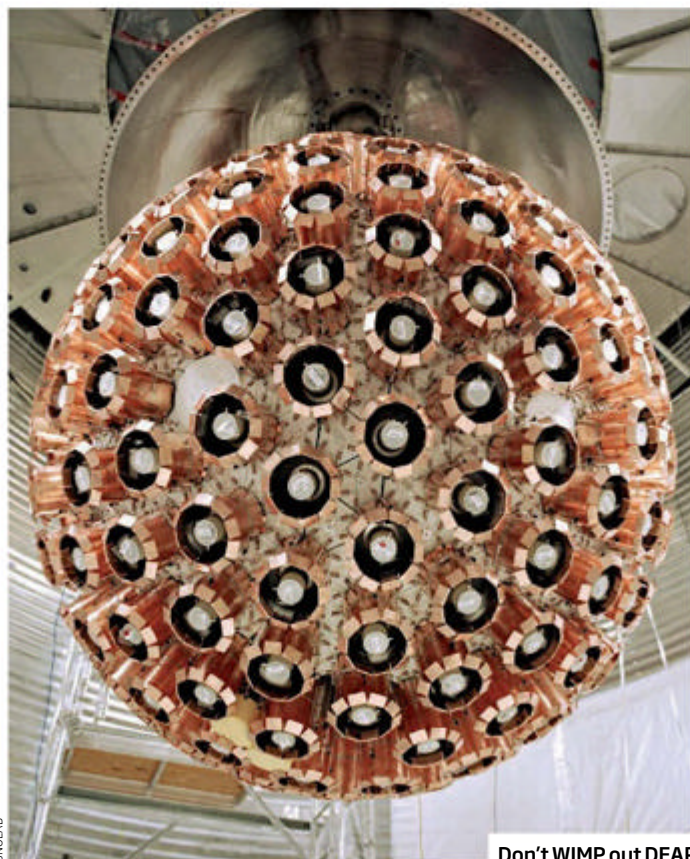
“Most theoretical model predictions give a WIMP mass that is greater than 100 giga-electronvolts, which happens to be a mass range where DEAP is more sensitive compared to other experiments,” he says.

At the end of my tour, I trudge back towards the cage with a flock of tired miners and physicists.

An announcement over the loudspeakers brings everyone to a sudden halt: “All stations, all stations.” Dunger looks at me apologetically. The cage is broken and we need to wait at the nearest refuge station until they can fix it.

“That's why you should always keep your lunch box nearby,” a broad-shouldered miner grins. “Once we were stuck for 24 hours.”

Luckily, this was not quite our fate. But 6 hours later, after more than 12 hours underground, we emerge into the cold Canadian night, leaving DEAP to begin its quest. ■



Don't WIMP out DEAP



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Life's not a beach

BILL CURTIS/INTERNATIONAL GEOGRAPHIC CREATIVE

driven by other factors?

Kimberly Reich and her colleagues at Texas A&M University in Galveston presented data at a February meeting in Houston, Texas, showing that the turtles stopped foraging on the seabed in areas contaminated by oil. But there's no proof that this affected survival and precipitated the collapse of nest numbers.

Other possible factors behind the drop include cold weather and the turtle population outgrowing the gulf's capacity to support it, two explanations favoured by BP, which owned the oil rig.

"Nest counts alone are not enough to point the finger at BP, as there are a number of things that could affect nest numbers," says Heppell. But, we've never seen such a dramatic drop in one year as in 2010, she says. Also, the recovery came to an abrupt halt, and didn't slow gradually as we might expect if it were coming to some sort of environmental carrying capacity.

"Long-term research is critical to finding out the real answer," says Benny Gallaway, president of LGL Ecological Research Associates in Bryan, Texas. But with cuts in turtle research funding from the US Fish and Wildlife Service, and secrecy over ongoing legal cases against BP, this may prove hard to do. ■

Messy legacy of Gulf oil spill

Andy Coghlan

THERE'S something amiss with iconic marine animals in the Gulf of Mexico. Five years on from the largest oil spill in US history, effects are still lingering. Sea turtle populations are in retreat, dolphins are in poor shape and whales are avoiding their usual hunting grounds.

The explosion of the Deepwater Horizon rig on 20 April 2010 killed 11 workers and the subsequent oil spill wreaked havoc on the region's wildlife. There was an immediate reverse in the recovery of the world's most endangered sea turtle. Until that

point, the number of nests of the Kemp's ridley turtle, which neared extinction in the 1980s, had been growing for two decades.

To what extent the oil disaster is to blame is still under debate, but the matter is shrouded in mystery, partly because ongoing litigation over compensation means that few scientists are prepared to discuss their data publicly.

Most Kemp's ridleys lay their eggs on beaches in the Tamaulipas region of north-eastern Mexico. A joint Mexican and US programme, launched in 1978, had put the turtles on the route to recovery: the number of nests rose by 15 per cent per year

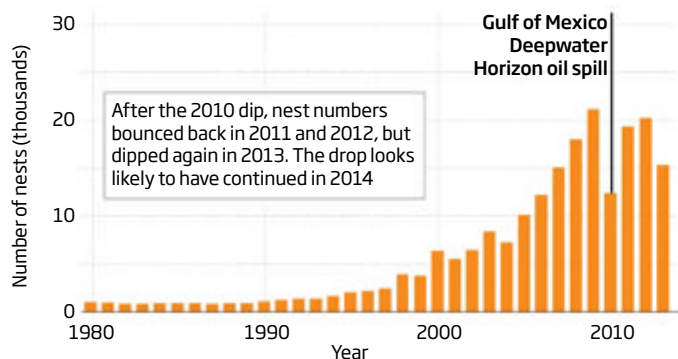
on average, from a record low of 702 in 1985 to 21,000 in 2009.

Then, in 2010, it all started to unravel (see chart, below). "Suddenly, the number of nests counted at the primary nesting beaches plummeted by nearly 40 per cent," says Selina Heppell of Oregon State University in Corvallis. Although nest numbers returned to 2009 levels in 2011 and 2012, they did not resume the increasing trajectory. "Now, the number of nests is declining, with 2014 showing the lowest number since 2006," says Heppell.

Was the 2010 collapse and slowdown in recovery caused by the spill, or was it a coincidence

Slick story

The rise in the number of Kemp's ridley turtle nests in the Tamaulipas and Veracruz regions of Mexico took a hit in 2010, when the Deepwater Horizon oil spill occurred



SOURCE: MARINE TURTLE NEWSLETTER 14(3)-7, 2014/WWW.NMFS.NOAA.GOV

BEYOND TURTLES

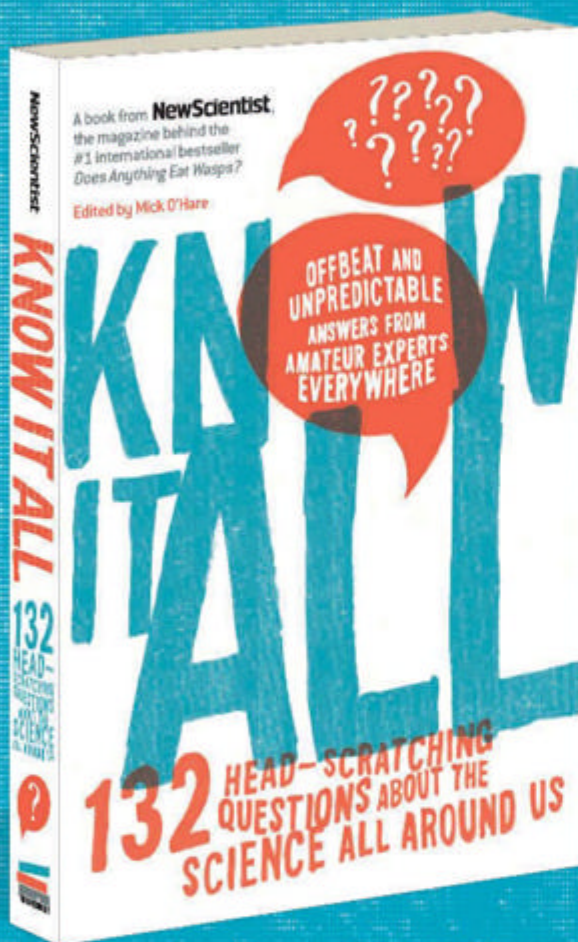
TURTLES aren't the only animals that seem to have been affected by the 2010 Deepwater Horizon oil spill. In February, at the 2015 Gulf of Mexico Oil Spill & Ecosystem Science Conference in Houston, Texas, several teams presented data on large mammals.

Bottlenose dolphins caught between 2011 and 2014 in Barataria Bay, Louisiana - close to the spill zone - were more likely to have lung disease and poor body condition than those caught in Sarasota Bay in Florida, which was unaffected by the spill. Those from the spill zone had

changes in their immune system that left them more vulnerable to bacterial infections, especially *Brucella*, which is linked with newborn dolphin deaths.

And six sperm whales, tracked between 2010 and 2013, didn't forage in a region of the seabed that covered 4000 square kilometres and included the spill site, an area whales had been tracked visiting between 2001 and 2005. This could be because contamination has reduced bottom-dwelling fish and the squid that feed on them, which are in turn prey for whales.

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Vampire squid takes a rest during reproduction

IT'S a tough life deep in the ocean, so you can't really blame the vampire squid for taking a break. All other species of soft-bodied cephalopod studied so far produce their offspring in one glorious bout of reproduction, usually just before they die. But not the vampire squid.

This sinister-looking creature feeds on zooplankton and decaying organic material in its struggle to survive up to 3000 metres deep.

Henk-Jan Hoving at the Helmholtz Centre for Ocean Research in Kiel, Germany, and his team dissected 43 female squid captured in tow nets off the coast

of southern California. They found 20 adults that had released some eggs, but still had immature egg cells available for future spawning. One squid had released at least 3800 eggs, judging by her empty follicles, but still had around 6500 left.

Based on the number of eggs the team observed ripening together in batches, they estimated the squid release about 100 eggs at a time – suggesting this female had already undergone at least 38 bouts of spawning, and could have gone on for another 65 (*Current Biology*, doi.org/3vm).

This could be an adaptation to their cold, low-energy life in the deep ocean. “By reproducing in multiple cycles, it may allow vampire squid to make use of its low-calorie food source,” says Hoving.

Space geckos seen playing in zero g

SOMETIMES a little less gravity is all it takes to cut loose. For a group of geckos on a Russian spacefaring mission, the extra lift of zero *g* appears to have been all they needed to engage in a bit of unprecedented tomfoolery.

The 15 “geckonauts” took off in April 2013 on board the uncrewed Bion-M1 satellite. One gecko wriggled free of its coloured identification collar before take-

off, and the collar spent the 30 days of orbital flight floating around its enclosure. On-board cameras captured the geckos – which did not float because of their sticky skin – nudging the collar around with their noses (*Journal of Ethology*, doi.org/3qb).

It's a highly unusual display of play in a reptile, says herpetologist Gordon Burghardt of the University of Tennessee in

Knoxville, who was not part of the study. He had previously argued that reptiles rarely play because most have to fend for themselves from birth, and – being cold-blooded – have little surplus energy for activities that don't immediately affect their survival.

He has also suggested that environments where reptiles need to burn less energy might give them enough juice to fool around. You can hardly blame him for not thinking of geckos in space.

Chimps are smart about road crossing

SCREEECH! Bang! It's the sound we all dread when crossing busy roads. Now it turns out that wild chimps learn to respect roads, adopting the same cautious drills as humans, including looking both ways to check for traffic.

Marie Cibot of the National Museum of Natural History in Paris, France, and her team analysed 20 instances of wild chimps crossing a busy road in Sebitoli in Uganda. They watched 122 chimps cross a highway used by 90 vehicles an hour, many speeding at 70 to 100 kilometres per hour. Ninety-two per cent of them looked right, left or both ways before or during crossing, and 57 per cent ran across (*American Journal of Primatology*, doi.org/3sf).

“Road infrastructure is spreading throughout Africa,” says Cibot. “Studying chimpanzee adaptation represents a way to reduce the risk of collisions.”

Stars throw out carbon in a flurry

WHEN cosmic carbon leaves home, it may move in a real rush, according to the first sighting of a star spewing it into space.

Ageing stars build elements like carbon in their core. These are eventually shed when stars throw off their surface layers, but no one knew exactly how the elements move outwards from the core.

Lizette Guzman-Ramirez of the European Southern Observatory and colleagues looked at a gas cloud around an older sunlike star. They found an outer oxygen-rich layer around a carbon-rich one. By modelling how the gap between the layers evolved, they calculated the star took 1000 years to dredge up its carbon (arxiv.org/1504.03349) – equivalent to 40 minutes in a human lifetime.

Puppy-dog eyes bond us to our pet

EVER felt adoration for your pooch when it stares at you? Man's best friend may have hijacked a uniquely human bonding mechanism.

When humans bond, eye contact leads to release of the "love hormone" oxytocin, which elicits caring behaviour. This in turn causes the release of more oxytocin. Using eye contact as part of this cycle was thought to be uniquely human, although oxytocin helps other mammals bond, too. "Facing others is a threatening behaviour in other animals," says Miho Nagasawa at Azabu University in Japan.

But when her team made dog owners gaze into their pets' eyes, oxytocin levels rose both in the humans and the dogs, an effect that was not seen with hand-reared wolves. They then sprayed either oxytocin or a placebo into 27 dogs' noses. Female dogs that got the hormone stared longingly at their owners for longer, and oxytocin levels also rose in those people (*Science*, doi.org/3rw). Male dogs didn't respond in this way, perhaps because oxytocin can also boost hostility in males.

Nagasawa says the tendency to gaze into our eyes must have evolved as dogs were domesticated. It's the first case of convergent evolution in cognitive traits between humans and another species, she adds.



AMBERHALLER/GETTY

Jolt of java helps spermbots in final race to the finish

CAFFEINE gives you a spike of energy before you crash back down – even if you're a robot made from bull sperm.

Spermrobots, as they are called, were first developed in 2013 by Veronika Magdanz of the Leibniz Institute for Solid State and Materials Research in Dresden, Germany, and her colleagues. She wanted to create a microscopic robot that could be used to deliver drugs around the body, and realised that sperm cells come with a built-in propulsion system: their flagellum.

The team trapped the heads of bovine sperm cells inside microscopic metallic tubes, then used a magnetic field to control their direction of travel, like a compass needle aligning with Earth's magnetic field. Since then, they've been looking for ways to boost the bots' performance.

Caffeine makes sperm go faster in humans, so the team tried adding some to the spermrobots' swimming pool. The sperm absorbed the caffeine and increased their speed by 30 per cent on average, but only for

around 30 seconds. A minute later, the spermrobots were flagging at around 70 per cent of their original speed (*Advanced Functional Materials*, doi.org/f266dh). "The speed boost is only useful for a final 'race to the finish line' of the spermrobots, when they need to be accelerated for a short time before they finish their task," says Magdanz.

Magdanz is also investigating how spermrobots could be used in reproductive technologies, such as the controlled delivery of a single sperm cell.

A snapshot of pre-modern gut flora

AND the prize for the most varied population of gut bugs goes to... the Yanomami people. Isolated for thousands of years, these hunter-gatherers live in the rainforests of south Venezuela.

When the government made contact with one particularly isolated village in 2009, scientists tagged along and took fecal samples from the villagers to see what pre-industrial gut flora looked like. They found that the villagers had nearly double the diversity of microbial species compared with people in the US. They also had about 40 per cent more than another group of Venezuelan hunter-gatherers that has occasionally used antibiotics and eaten processed foods (*Science Advances*, doi.org/3tw).

Team member Jose Clemente of the Icahn School of Medicine at Mount Sinai in New York says this suggests that even minimal exposure to modern lifestyles can cause a dramatic loss of microbes. Whether this negatively affects health is an open question.

Alas, the accolade of having the most diverse gut flora may turn out to be short lived. Medics with the researchers gave some of the villagers antibiotics.



ANDERS WASHMAN

Seabed perfect place to store bubbly

"ANIMAL notes" and "wet hair" were the terms used to describe 170-year-old champagne hauled up from the Baltic Sea in 2010. It now seems the wine has aged well, although the mystery over how it got there is even murkier.

Seals on the corks showed that the 163 bottles came from the illustrious Veuve Clicquot Ponsardin, Heidsieck and Juglar houses. After three of the Veuve Clicquot bottles were tasted by oenologists, 2 millilitre samples from each were sent for chemical analysis. It turned out that the grape juice in the wine hadn't turned to

acetic acid, probably because of the cool temperatures and dark environment of the sea floor (*PNAS*, doi.org/3v4).

The bottles' location suggests they were on their way from Germany to Russia when they sank, some time in the early 1800s. Russians at the time liked their bubbly very sweet and Madame Clicquot made special extra-sweet batches for them. But Philippe Jeandet of the University of Reims Champagne-Ardenne, France, who analysed the wines, says they were too dry for Russian palates.



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1. Official EU MPG test figure shown as a guide for comparative purposes and may not reflect real driving results. 2. 32 mile EV range achieved with full battery charge. 510 miles achieved with combined full battery and petrol tank. Actual range will vary depending on driving style and road conditions. 3. Domestic plug charge: 5 hours, 16 Amp home charge point: 3.5 hours, 80% rapid charge: 30mins. 4. Government subsidised charge points are available from a number of suppliers for a small fee - ask your dealer for more information. 5. Congestion Charge application required, subject to administrative fee. 6. 5% BIK compared to the average rate of 25%. 7. Prices shown include the Government Plug-in Car Grant and VAT (at 20%), but **exclude First Registration Fee**. Model shown is an Outlander PHEV GX4h at £33,399 including the Government Plug-in Car Grant and metallic paint. On The Road prices range from £28,304.00 to £40,054.00 and include VED, First Registration Fee and the Government Plug-in Car Grant. **Metallic/pearlescent paint extra**. Prices correct at time of going to print. For more information about the Government Plug-in Car Grant please visit www.gov.uk/plug-in-car-van-grants. 8. All new Outlander PHEV variants come with a 5 year/62,500 mile warranty (whichever occurs first), for more information please visit www.mitsubishi-cars.co.uk/warranty

Outlander PHEV range fuel consumption in mpg (ltrs/100km): Full Battery Charge: no fuel used, Depleted Battery Charge: 48mpg (5.9), Weighted Average: 148mpg (1.9), CO₂ Emissions: 44 g/km.

Every breath you take

Lurking inside a future internet router, a radar-like system could watch your heartbeat, breathing and mood – without you even noticing

Hal Hodson

IT HAPPENS the moment you walk in: without you being aware of it, an undercover system discreetly records your breathing and heartbeat. Welcome to the Katabi Lab, part of the Computer Science and Artificial Intelligence Laboratory at the Massachusetts Institute of Technology.

Called Vital-Radio, the system needs no sensors attached to the body, yet is nearly as accurate as conventional methods. Its measurements are wireless and even work through walls, so can keep tabs on your vital signs as you watch TV in the lounge or read or sleep in the bedroom. The team behind it believe it could be used to monitor and improve patient health in hospitals and at home.

“Breathing and heart rate would be interesting in hospitals if you want to monitor people without having things on their body,” says team member Fadel

Adib. But the system could have a more surprising application: inferring our emotional state. What’s more, it could be built into a home Wi-Fi router, making it a hub not just for internet connections but also for collecting health data.

Vital-Radio works like a bit like radar: it transmits using a part of the radio spectrum similar to that used for Wi-Fi, then watches the reflected signals for imprints that indicate life. It also measures how long it takes the reflected wave to return – its “time of flight”. Each object in the vicinity, people included, will reflect the signals with a slightly different flight time depending on distance from the antenna.

The system then analyses the signals for the telltale signs that they bounced off a human – usually modulations that indicate movement. The rising and falling of our chest creates a distinct signature, and even the pulse in

our neck, imperceptible to the eye, can be seen in the reflected signals. The team presented Vital-Radio earlier this week at the CHI computer conference in Seoul, South Korea.

Although the obvious applications lie in remote health monitoring, the physiological signals the system picks up often

“The rising and falling of our chest, even the pulse in our neck, can be seen in the reflected radio signals”

betray something that computer scientists are increasingly interested in – our emotions.

Call centres already use software to “read” how callers feel from their tone of voice, helping their workers make decisions. Vital-Radio could do a similar thing for the technology we interact with, all without needing us to don any extra gadgets.

A modified Wi-Fi router

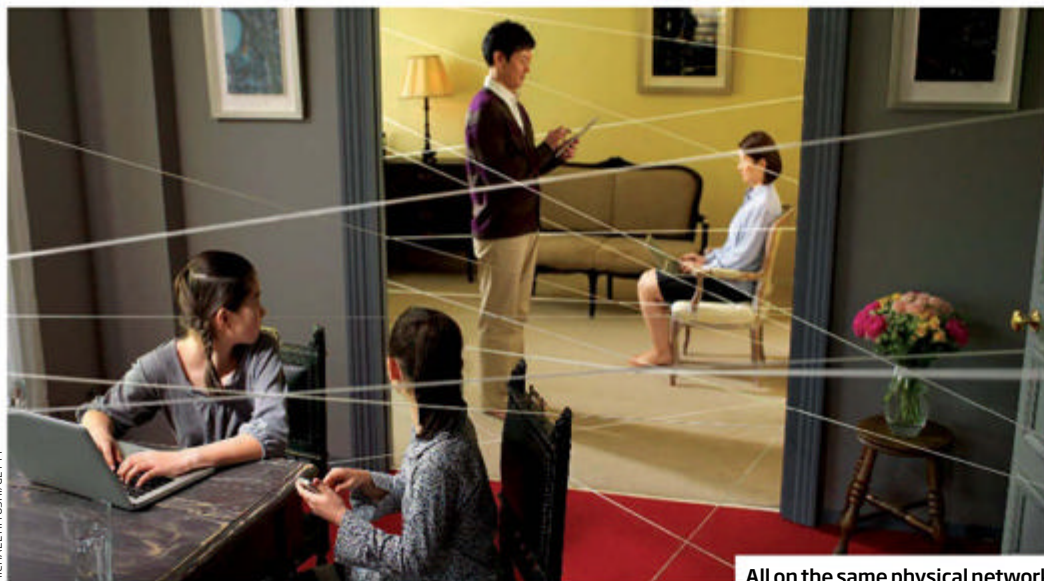
incorporating the system might tell our laptop that the movie we’re watching is calming us down, prompting the laptop to hold off displaying alerts, except for truly urgent matters. Smart lighting or music systems could change their hue or the music they play to match or moderate our mood.

Adib says the group is honing the system to the point where it can monitor a fetus’s heartbeat inside its mother. It may one day even be able to monitor the heartbeat in detail, acquiring data comparable to an electrocardiogram without the need for a hospital visit.

The biggest challenge for systems like Vital-Radio, according to Changzi Li of Texas Tech University in Lubbock, is how to deal accurately with the fact that people don’t sit still. “A heartbeat is 1 millimetre or smaller. Any random body motion could be much larger than the signal you want to capture,” says Li.

For this reason, Vital-Radio doesn’t try to monitor a person’s heart and breath rate while they wander about. But the technology it relies on can be used to track you as you move around the house, for instance. It can also track specific gestures and body language. A home with the system installed and connected to the lighting system would, for example, let residents control lights with a wave of their arm, much like using a Kinect can.

“There’s going to be a lot of applications,” says Li. “Not just in home but hospitals too. If the technical problem is solved, then the first hit will be in routine health monitoring.” ■



All on the same physical network



MADS PERCH/GETTY

Tuned in

Digital tattoo behind the ear can read your mind

WHAT'S on your mind? For £79, anyone can buy a headset that reads the electrical activity of their brain. It's called an electroencephalogram, or EEG, and you can use it to control devices with the power of your mind. But there's a drawback: they don't work when the wearer is moving and they look silly, so no one wants to wear them.

The solution could be a kind of EEG system that does away with the cumbersome electrodes, annoying gels and wires of its predecessors, replacing them with a flexible electronic skin that conforms to the body. It promises to let us monitor our brains discreetly 24 hours a day, and can be worn continuously for two weeks, staying put whether you're swimming, running or sleeping.

John Rogers at the University of Illinois at Urbana-Champaign led the team that built the device, which is so light that it sticks to the skin through van der Waals force – the same mechanism that lets geckos' feet stick to surfaces. It only falls off when the build-up of dead skin beneath it makes it lose its grip.

Comprising just a small patch of gold electrodes on and behind the

ear, it beats the existing tech, described by Rogers as a "rat's nest of wires attached to devices that interface to the skin with tape and gels and bulky metallic objects".

To test it, the team looked at their system's performance in tasks that clinical EEG devices usually handle. For example, volunteers were able to spell out the word "computer" on a screen in front of them using their brains' electrical activity.

Their stick-on EEG was wired up to a computer for the tests, but the team is working on wireless transmission of data and power, something they have already achieved in other devices.



B-NE BIO-INTERFACED NANOTECHNOLOGY LAB

Good as gold

The focus is on medical applications to begin with – "EEG is important in detecting seizures – particularly in premature babies," says Rogers. But the fact that it can sit discreetly behind an ear means that all kinds of other applications are feasible.

"It might start a coffee pot brewing in the morning when your brain activity implies you're waking up"

No one wants to wear a headset constantly, but applying a hidden electronic tattoo once every two weeks is more acceptable.

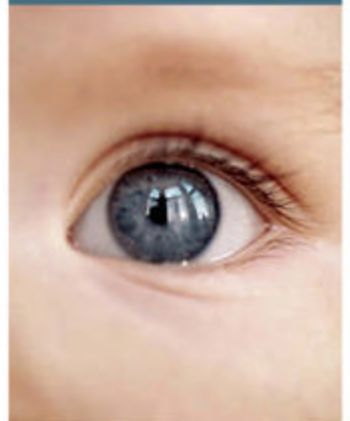
Although Hidden EEG can't rival the precision of the keyboard and mouse from your desktop computer, it is good for controlling systems in a more passive manner. Instead, it might start a coffee pot brewing in the morning when your brain activity implies you're waking up. Or, if the device reads that you're in a highly focused state, it could tell your phone to silence any notifications.

"What we need is to measure EEG unobtrusively, invisibly," says Stefan Debener of the University of Oldenburg in Germany, whose lab has developed its own version of an in-ear EEG system. He says that in tests on his own system, half the subjects forgot they were wearing the sensors. "This is exactly what you want," he says. "You want tech that merges with the user."

Debener is working on a way to measure the attention of a hearing aid user through EEG, then tune the hearing aid in to the voice they are concentrating on. Modern hearing aids can already focus on a single source in a noisy environment, but with EEG, they would be able to detect what their wearer wants to listen to.

"The limitation of EEG so far has been that we didn't have the technology to study the brain in nature non-invasively," says Debener. "This is a huge limitation. It's very hard to tell how decisions are made in complex environments. If you could do this with EEG on the street, driving a car, that would make a big difference." Hal Hodson ■

ONE PER CENT



Blur, blur, mummy!

See the world through a baby's eyes. BabySee, an app built by an ophthalmologist at Boston Children's Hospital, tweaks the scene your phone camera captures so it appears more like it would to an infant. A slider alters the view according to age: a newborn might only see a dim, blurry image, while a 6-month-old can pick out more colours and features.

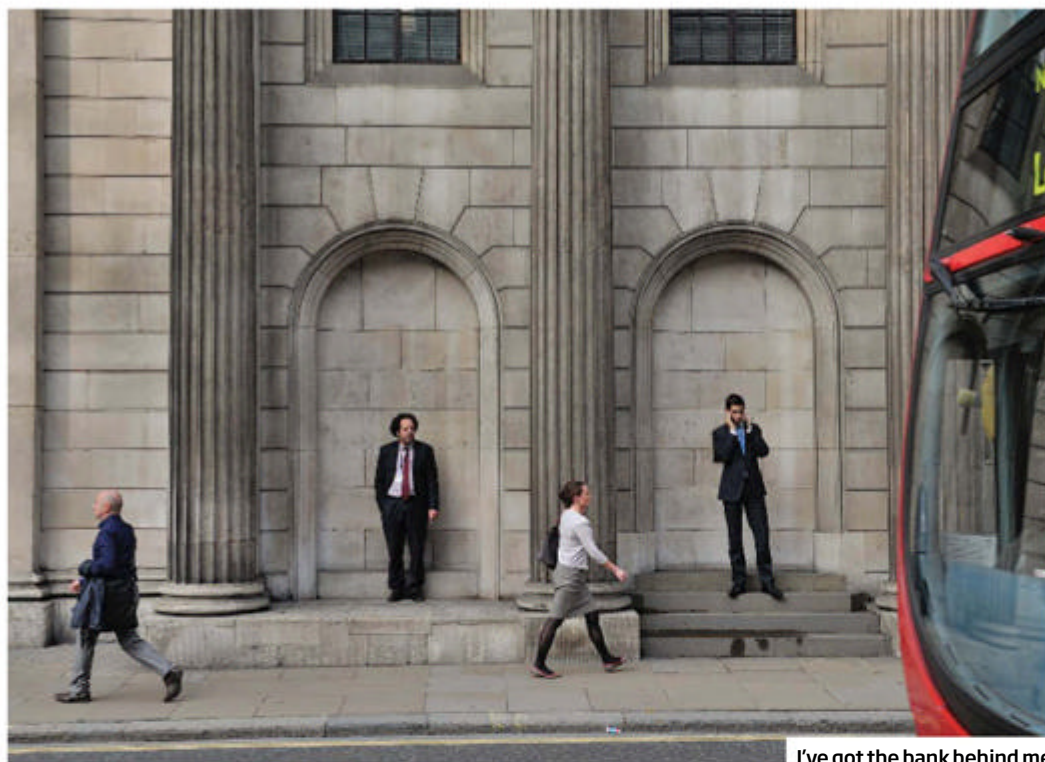
590

The speed in kilometres per hour that Japan's maglev train hit last week, breaking the previous world record of 581 kilometres per hour set in 2003

The robot that could

Heave! A little robot can scale walls while hauling a load 100 times its weight. The bot, built by Elliott Hawkes's team at Stanford University in California, weighs 9 grams, but can hoist more than a kilogram. It sticks to walls with two pads and moves like an inchworm: one pad scooches it forward while the other stays in place to support the heavy load. A smaller version weighs just 20 milligrams and can carry 500 milligrams, about the weight of a small paper clip.

RODERICK CHENG/GETTY



I've got the bank behind me

Bank on phone credit

Just using a smartphone can help bag you a loan, says **Aviva Rutkin**

WHEN Kyle Meade first moved to the US from Canada, he just couldn't get a loan. "I had no debt, no previous information on me in the US," he says. "The highest I was offered was \$300, because I'm credit thin."

For Meade, innovation director of credit-scoring company Entrepreneurial Finance Lab (EFL), the situation was ironic. For millions of people around the world, particularly those in developing countries, it's a frustrating reality. Without a robust financial history, banks have trouble gauging how risky a person is, and are hesitant to give them the loan they might need to start a business, buy a house or go to school. What do you do when the system rejects you?

One answer could be to pull out your phone. A handful of finance

start-ups are betting that metadata – the vast amount of data amassed by our cellphones or internet activity – can drive a new generation of banking.

Daniel Björkegren, an economist at Brown University in Providence, Rhode Island, is working with EFL to predict whether someone will pay back a loan based on their cellphone data. He combed through the phone records of 3000 people who had borrowed from a bank in Haiti, looking at when calls were made, how long they lasted and how much money people spent on their phones.

The algorithm looks at this metadata to get a sense of a person's character. Do they promptly return missed calls and pay their phone bills? That suggests they might be more responsible. Are most of their

calls made in an area far away from the bank branch? Then it may be hard for the bank to keep tabs on their whereabouts.

Björkegren found that the bank could have reduced defaults by 43 per cent by using the algorithm

"Do people promptly return missed calls and pay their phone bills? That suggests they are responsible"

to pick better people to give loans to. The results were presented at the NetMob conference in Cambridge, Massachusetts, earlier this month.

Since many use their phones daily, the metadata can reflect changes in people's lives very quickly, says Qiuyan Xu, chief data scientist at Cambridge start-up Cignifi. Cignifi is studying how

mobile data might be used to predict whether people will repay loans and how much money they will save. Their research has found that the time of day people make calls and the sorts of neighbourhoods they are calling can be useful indicators.

"Mobile data touches our daily lives," Xu says. "It's a powerful way to predict user behaviour."

The idea carries some risks, says Yanhao Wei at the University of Pennsylvania in Philadelphia. For example, companies might be unduly suspicious of people who opt out of sharing anything. "You may give people the choice to give data or deny data, but in those cases, denying itself is a bad sign," says Wei. There's also the question of privacy – how can a program sift through all this data while still keeping it secure?

Still, several start-ups have already tried making the jump. Inventure in Santa Monica, California, makes an app that monitors phone use and helps people keep track of their daily cash flow, information that then combines with demographic data to produce a credit score. In a pilot project last year in South Africa, Inventure gave out smartphones on credit to a small pool of people, who then used the app as they paid the company back.

Another start-up, Lenddo, has brought its algorithm to the Philippines and Colombia. This also looks at a person's social media accounts – Facebook, Twitter and LinkedIn – counting how many people someone is connected to, how often they interact and whether their online friends have good credit scores themselves. The software has helped people get loans for phones and motorcycles.

"Although many individuals who want to take out loans in developing countries don't have financial histories, they do have mobile phones," says Björkegren. "For the first time, it's possible to get detailed data about people who are marginalised economically." ■

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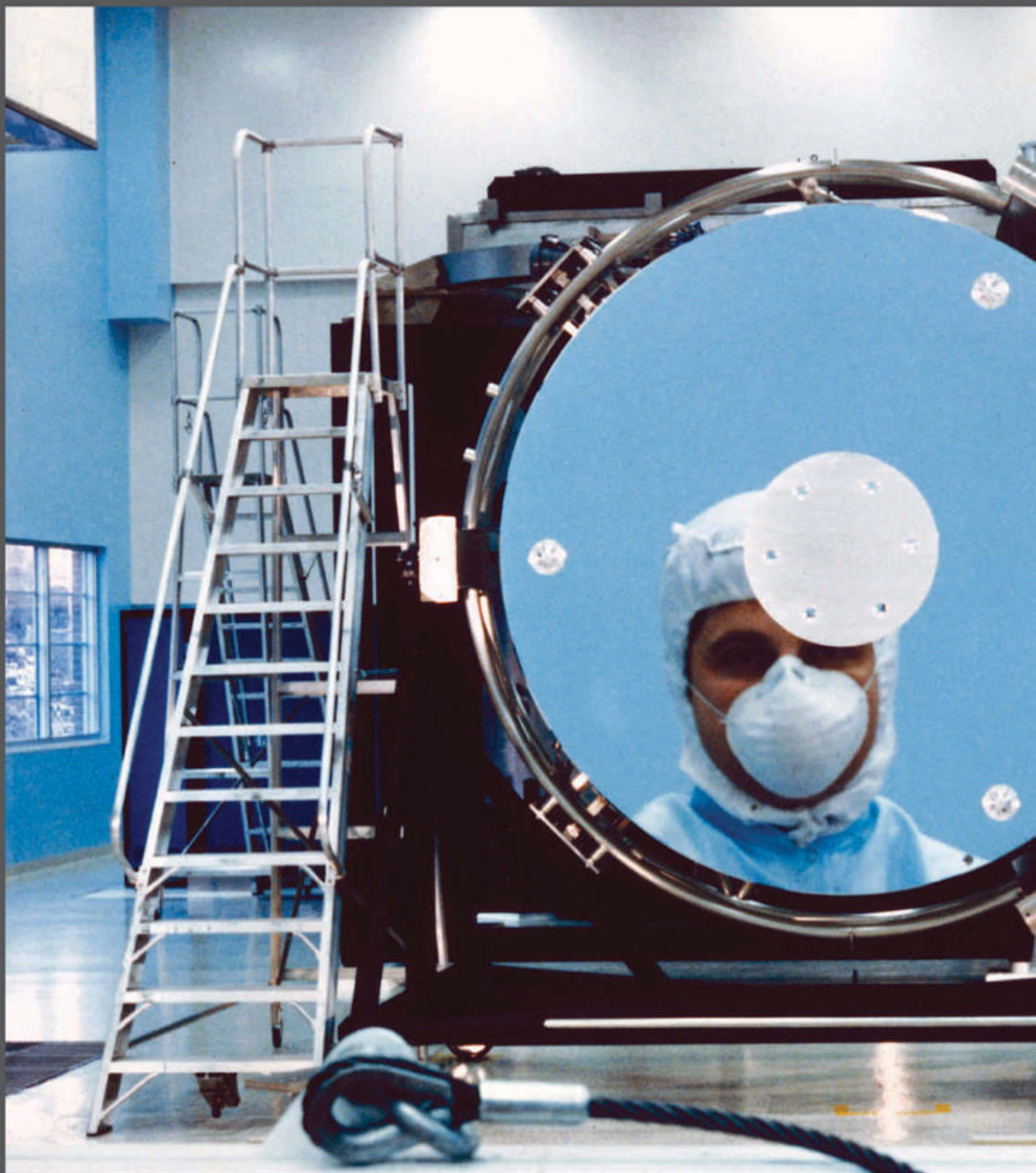
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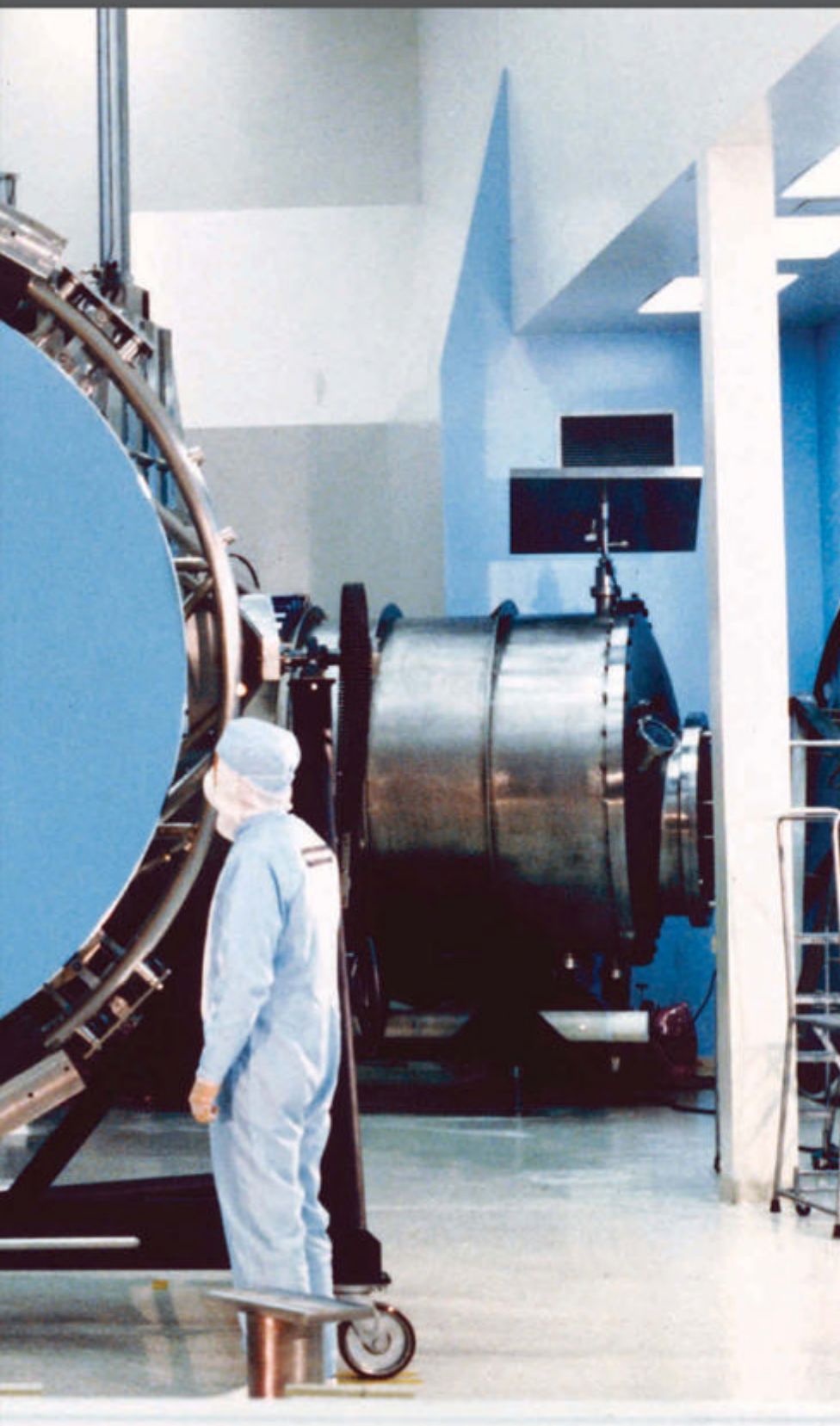
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Hubble's ocean of glass

THE Hubble Space Telescope has for the past 25 years powered NASA's dream of putting people into space. Launched on 24 April 1990, it was designed to be looked after by flesh-and-blood astronauts, and repairs and maintenance have run up a bill that would have paid for several new telescopes. But what would have been the point of that?

Hubble has been the training ground for a generation of spacefarers. Servicing it has taught NASA everything it knows about building and maintaining the International Space Station. It is also a very fine instrument indeed. Its work is celebrated in Taschen's new book *Expanding Universe*, which intersperses pictures taken by Hubble, like the one of the variable star Monocerotis below, with images of Hubble's planning and construction. This includes the photo of the 2.4-metre primary mirror shown on the left, which is so smooth that if you were to scale it up to the size of the Atlantic Ocean, its waves would be less than 10 centimetres high.

Statistics like this have inspired film-maker Chris Riley to celebrate the telescope in *Hubble's Cosmic Journey*, a film for the National Geographic Channel that was first screened on 18 April. He has managed a major coup. Optical engineer Bud Rigby and his colleagues at Perkin-Elmer, who made the mirror, shouldered the blame for an optical flaw that took three years to correct. Twenty-five years on, vilified by the press and their own colleagues, the men at first refused to participate. Luckily, Riley's persistence paid off, and their extraordinary technical achievement is finally being recognised. Simon Ings



NASA, ESA AND THE BOND STSC

Photograph SSPL/Getty

These images and more appear in *Expanding Universe*, published by Taschen (£44.99/\$69.99)

Defying gravity

Tax breaks for the wealthy were meant to trickle down through society and boost everyone. It didn't work, says **Ha-Joon Chang**

ADVOCATES of trickle-down economics argue that, when the rich get extra income, they invest it and create more jobs – and a higher income – for others. Those people, in turn, spend their extra money. Eventually the effect trickles down the whole system, making everyone better off, in absolute terms.

So, what seems like a moral outrage – giving more to people who already have more – is in theory a socially benign action.

The trouble is it hasn't worked. In the past three decades, states with pro-rich policies have seen economic growth slow, except in countries like China and Vietnam that needed to jump-start socialist economies.

In the UK, upward income redistribution since 1980 has seen the share of the top 1 per cent rise from 5 per cent of national income to over 10 per cent. Yet the



annual growth rate of income per person has fallen from 2.5 per cent between 1960 and 1980 to 1.8 per cent between 1980 and 2013.

One reason is that the rich have not kept their end of the bargain – they didn't invest more; and inequality, linked to poorer health and societal damage, worsened. Investment as a share of GDP used to be 18 to 22 per cent in the 1960s and 1970s but since then has been 14 to 18 per cent, except for a few years at the end of the 1980s.

Moreover, concentration of income at the top has boosted the political influence of the super-rich, allowing them to push for policies that benefit themselves but create harm in the long run. For example, the UK financial sector successfully lobbied for “light-touch regulation”, which enabled it to earn a lot but led to the 2008 financial crisis.

It is well established that a less

Feel-good factors

It's time to let national happiness guide political policy, says **Richard Layard**

MORE than 200 years ago Thomas Jefferson declared: “The care of human life and happiness... is the only legitimate object of good government.” The third US president's advice was finally taken in 2011, when the UK began the continuous measurement of national well-being. Since then all rich countries have followed suit.

Has this made any difference? In opposition, UK Conservative leader David Cameron embraced a new approach: “It's time we admitted there's more to life than money, and it's time we focused not just on GDP [gross domestic product], but on GWB – General Well-Being.” In practice it is hard to see much sign of this during his

five years as prime minister, when the economy and cutting public services were firmly centre stage.

Making improved well-being the focus of policy would have produced very different priorities. Every survey of happiness shows that family income accounts for only a small variation in happiness across the population. Much more important are health, family relationships, community life and youth employment. Whoever leads the country after

the election in May, we need to see a new focus on support for parents and young people.

Professional help for people experiencing domestic violence and family conflict, as well as children in difficulty, must be provided. Schools need to have the well-being of pupils as an explicit goal. Personal, social and health education need to be statutory and taught by well-trained staff. Child mental health services need to grow and become more modern, and therapy services for adults need to double. Young people need a right to an apprenticeship or a course that leads to one.

Some of this will be in party

“Making well-being the focus of policy would have led to different priorities over the past five years”

equal society has lower social mobility. When talented people from less privileged backgrounds cannot move up the social ladder, the economy's long-term dynamism suffers. An increasing number of studies show that, above a certain level, higher inequality harms growth. Some are by the International Monetary Fund and Organization for Economic Cooperation and Development, which didn't use to be concerned about inequality.

Despite these failings, some politicians still back measures that benefit the wealthy, often citing trickle-down economics. In the UK, the Conservatives cut taxes for the top earners while in government. They want to slash inheritance tax for wealthier estates and cut the numbers paying higher-rate tax. The UK Independence Party has a similar stance on higher-rate tax and wants zero inheritance tax.

The 35-year experiment with trickle down economics has failed for most people. Unfortunately, there is too much money and power at stake for its true beneficiaries to accept this reality and end this approach. ■

Ha-Joon Chang is an economist at the University of Cambridge. His latest book is *Economics: The user's guide* (Pelican)

manifestos. But we really need an institutional shift. Treasury rules say policies should be judged by how much people would be willing to pay for the benefits they bring. A new approach in which policies are based on their effects on happiness is needed.

This was suggested by a high-profile, independent assessment last year and repeated in the third *World Happiness Report*. It is an idea whose time has come. ■

Richard Layard is a founder of the Centre for Economic Performance at the London School of Economics, a Labour peer and an author of the third *World Happiness Report*, out this week

ONE MINUTE INTERVIEW

Project placenta

It's time to get to know the human body's least understood organ, says **Cathy Spong**



PROFILE

Cathy Spong is an obstetrician who specialises in high-risk pregnancies. She is deputy director of the Human Placenta Project at the US National Institutes of Health in Bethesda, Maryland

What is so interesting about the placenta?

The human placenta is unique – it's the only organ that you discard after it grows. And you might grow another one and discard that too. It does many jobs that other organs do. It provides nutrition to the baby, and functions as its lungs, kidneys and immune system.

Don't we already have a reasonable understanding of the placenta?

No, the placenta develops over time just like the baby, yet most of the research is on placentas delivered at birth. That only gives you a snapshot. One of the reasons we launched the Human Placenta Project is that there have been huge advances in technology in other medical fields that have not yet been applied to pregnancy. We aim to develop tools to better understand what's happening, in real time, throughout the process.

Can't ultrasound tell you what you need?

As an obstetrician, I use ultrasound all the time, but that just gives us a picture of the placenta.

It doesn't tell us what's going on with its metabolism, whether it's providing the baby with the right nutrients and right amount of oxygen, what genes are being turned on, and so on.

How do those things affect the pregnancy?

If the placenta develops abnormally, that will affect how the baby grows and develops. It might cause the baby to be smaller or larger, and can result in premature birth. How the placenta develops may also underlie pregnancy-specific complications in the mother, like pre-eclampsia, a condition associated with high blood pressure. Other complications include placental abruption, when the placenta separates from the wall of the uterus too early. These conditions can harm both mother and baby.

Can placental development have long-term health impacts?

Yes, it may affect the lifelong health of both baby and mother. Mothers with pre-eclampsia have a higher risk of heart disease later in life. We don't know whether they get pre-eclampsia because they have undetected conditions that are only revealed by the "stress test" of pregnancy, or if you could prevent heart disease by stopping the placenta from developing abnormally. The placenta can even have transgenerational effects: babies born small have higher risks of complications like heart disease and cancer later in life, and that can affect the eggs or sperm of their own children.

How are you going to discover the placenta's secrets?

One way is to use available technologies, including ultrasound and MRI scans. It will also be essential to develop new tools. Hospital patients often have a pulse oximeter put on their finger to monitor their blood's oxygen status. Is there something similar that could be applied to the abdomen or cervix to monitor the placenta? We're right at the beginning, so it will be exciting to see what the project comes up with.

Interview by Clare Wilson

Chasing shadows

When the writer Arthur Koestler died, he left his estate to support parapsychology research. **Caroline Watt** helped set up the unit that bears his name. What has 30 years of research uncovered?

What drew you into parapsychology?

Some parapsychologists enter the field because they had a personal paranormal experience, but not me. I was curious to find out what might lie behind such experiences.

The term “parapsychology” can raise eyebrows. Do you encounter opposition to what you do?

There is occult baggage attached to the field, which is really not related to what we actually do. We are scientists. Sometimes other scientists describe parapsychology as a pseudoscience, and that’s unfair. I’ll stick my neck out and say that the methodological standards of parapsychologists are sometimes higher than those of psychologists. For example, since 2012 I’ve been operating a parapsychology study registry; psychologists are only now starting to take study registration seriously. Parapsychologists are making extraordinary claims, so we have to ensure our research eliminates as many artefacts and normal explanations as we can.

Do you approach your work as a sceptic or as a believer?

I try to look from both sides, but if someone has a paranormal experience, often there are normal psychological explanations.

What kinds of experiences do you study?

The most commonly reported experiences are of extrasensory perception (ESP), for example a person feeling that they know who is calling on the phone before actually answering it, or feeling they can dream about the future. Recently I’ve been working on these precognitive dream experiences.

Dreams can be interpreted in so many ways. How can you test whether people are truly dreaming about the future?

It’s true that with spontaneous, everyday dreams, you can find all sorts of meanings. The more creative you are, the greater the likelihood of finding a connection between your dreams and something in your life. When you are looking at real-world experiences, you can’t work out the chance probability of any dream coming true. So when it comes to testing dream precognition, you have to create an artificial scenario in the lab.

How do you do that?

You would have, say, four postcards, each one a different art print; nobody knows in advance what they are. One of them will be selected at random. The study aims to figure out whether people who claim to have precognitive experiences can dream about this event before it happens.

First, we ask the participants to sleep in a sleep lab. They know that in the morning they’ll open an envelope and see a picture.

“There is occult baggage attached to the field. That is not related to what we do”

The hypothesis is that their dreams that night will relate to the picture they will see. Everybody dreams five or six times a night, so we wake the participants up throughout the night and ask them to report their dreams. In the morning, we randomly select one of the postcards and show it to them.

Next, we get an independent person with no connection to the participant and who doesn’t know what postcard the dreamer saw. We ask this judge to rate which of the four postcards is most similar to the dream reports. By chance alone, we’ll get a match 25 per cent of the time, so that’s the baseline we’re working against.

What did you find?

Our research found no evidence that people’s dreams predict the future.

Why do people make such claims for dreams?

People remember dreams that seem to come true. Over time, and particularly if you believe in the paranormal, you would attend to those dreams, and that leads to the feeling you’re having lots of precognitive dreams. A normal psychological explanation is that you are selectively remembering dreams that seem to correspond to subsequent events and forgetting the dreams that don’t. But little research has been conducted on precognitive dreaming, so it is too early to say we fully understand what causes these experiences.

Have you looked at other phenomena?

I have studied the psychology behind ghost experiences, with Richard Wiseman. We went to very interesting locations, such as Hampton Court Palace in London and the underground vaults in Edinburgh. We had members of the public going around different areas of Hampton Court and the Edinburgh vaults and marking on a floor plan those spots where they were having unusual feelings, like the hairs standing up on the back of their neck, or chills. We built a map of the ghostly hotspots, and then we took physical measurements, such as the light level, draughts, temperature, humidity and so on, and tried to find if there were any physical factors that might be leading people to have strange experiences. ➤

PROFILE

Caroline Watt is a parapsychologist and a founding member of the University of Edinburgh’s Koestler Parapsychology Unit, which opened its doors in 1985





What was the outcome?

We found that aspects of the physical environment were associated with people's spooky experiences.

Is there any evidence for the paranormal?

Research using something called the Ganzfeld method has received a lot of attention. It's a way of testing for ESP. One person – the receiver – is in a room, bathed in red light, wearing headphones playing white noise and talking aloud about what's going on in their head. In another distant room, a sender is looking at a randomly selected target, which might be a picture or a video clip, and attempting to mentally communicate the image to the receiver. The verbal reports from the receiver are compared to four possible targets. It's a blind process; the person doing the comparison doesn't know the answer.

Again we know that if you have four possible targets you'd expect 25 per cent success by chance. Many such experiments have been meta-analysed several times and most of the analyses have come up with evidence suggesting a success rate greater than chance. They seem to be finding about a 30 per cent success rate.

That doesn't seem like a whole lot...

Well, small effects can be important. The statistician Jessica Utts has pointed out that the Ganzfeld effect size is triple the effect of aspirin on heart attacks. Many parapsychologists would argue that by the standards applied to any other area of science, that's good evidence, but I'm not persuaded

that this provides conclusive evidence for ESP. I am in the camp that thinks there is an anomaly, but I am not sure how to interpret it. One complicating factor is that when meta-analyses are conducted retrospectively, as they usually are, decisions made by the analyst can influence the outcome – which studies to include, for example.

What is the most startling thing you have encountered in your career?

I once conducted a study that obtained quite large effects supporting the ESP hypothesis. A few parapsychologists congratulated me, but I doubted the results. So I conducted a replication study, and discovered a subtle artefact in a computer program that accounted for the earlier positive results.

"I think there will be a material explanation for paranormal experiences"

This episode vividly demonstrated to me that a researcher's expectations can have a dramatic influence on the extent to which they scrutinise an experiment.

Is funding for this sort of research easy to find?

We're in an unusual situation. The Koestler Parapsychology Unit's funding came from a bequest. The writer Arthur Koestler, who was terminally ill, and his wife Cynthia killed themselves in a suicide pact in 1983. Koestler had a lifetime interest in the paranormal and dualism – the belief that the mind and body

are separate and distinct – and he left his entire estate to support parapsychology research at a British university.

Are you a dualist?

No. I describe myself as a materialist. I'm not a person who thinks there is an immaterial aspect to us. I think that there will be an explanation for paranormal experiences in material terms. But I don't think we will necessarily find a straight connection between paranormal experiences and, for example, unusual activity in the brain's temporal gyrus: there may not be a single explanation.

Do you sometimes wonder what Koestler would have made of a materialist running the research that he funded?

Materialism does not rule out the possibility of paranormal phenomena. If parapsychologists provide compelling evidence of paranormal phenomena, then I would expect there to be some adjustment to what we currently understand about physical laws and consciousness in order to incorporate this evidence.

Since the Koestler Unit began 30 years ago, dozens of PhD students have conducted their parapsychological research here, and some have gone on to establish new research units at other universities. I hope Koestler would approve.

Where do you think parapsychology will be in another 30 years?

I think parapsychology will probably disappear – we'll ultimately integrate it with neuroscience and psychology. Even if we find that there is some paranormal experience that cannot currently be understood by physics, I would expect that it could become integrated so that we can make sense of these experiences in physical terms.

Does the scarcity of evidence for parapsychological phenomena leave you feeling disappointed?

No. I'm not in this field to mystery-monger. I'm looking for answers to questions about people's paranormal beliefs and experiences. These questions are open to the scientific method, so we just need to do our research carefully and patiently.

Have you seen *any* evidence of what you would call psychic ability in your work?

Not indisputable evidence, no. ■

Interview by Anil Ananthaswamy



The hidden law

Nature's rules are encoded in symmetries – a penetrating insight from one woman working a century ago, says physicist **Dave Goldberg**

W E PHYSICISTS have a habit of depicting our discipline as “beautiful” or “elegant”, where an outsider might be forgiven for seeing no more than an endless morass of equations. In an ideal world, those equations would be unnecessary; the ultimate goal of physics – and science generally – is to describe the world as simply as possible.

One hundred years ago, one person brought us a great step closer. In this centenary year of general relativity, Albert Einstein is getting the plaudits, and no one would gainsay him that. But that same year, 1915, the excitement surrounding relativity spawned another

seminal piece of work. Even among physicists, though, it is not nearly as famous as it should be. Perhaps that is down to the complexity of its mathematics, but perhaps the author's sex and sadly short life played their parts too.

Yet there is no doubt that Amalie “Emmy” Noether transformed how we think about the universe. Despite the hairy mathematics, her great first theorem can be described conceptually in just a short sentence: *Symmetries give rise to conservation laws.*

This simplicity masks a penetrating insight. It provided a unifying perspective on the physics known at the time – and laid the

STUART FRANKLIN / MAGNUM PHOTOS



For physicists, the appeal of symmetry goes beyond the purely aesthetic

groundwork for nearly every major fundamental discovery since.

Emmy Noether is a story unto herself. Despite wide recognition of her obvious brilliance, she was confounded by the prejudices of German academic tradition at the turn of the 20th century. Born into a prominent mathematical family in 1882 – her father, Max, was a professor at the University of Erlangen in the north of Bavaria – she was at first forbidden from enrolling at the university because of her gender.

Even though Noether was eventually able to gain both an undergraduate degree and a PhD, still no university would hire her for their faculty. Over the next decade, she became one of the world's experts in the mathematics of symmetry – but without appointment, pay or formal title.

Symmetry may seem like a trifling subject at first blush. The mathematician Hermann Weyl, a contemporary of Noether's who was greatly influenced by her work, once described a very simple way of thinking about the concept: "A thing is symmetrical if there is something you can do to it so that after you have finished doing it, it looks the same as

before," he wrote. A circle, for instance, can be rotated by any angle and looks the same.

The idea that symmetries lie at the heart of physical laws is old. Aristotle and his contemporaries argued that the stars were pasted on celestial spheres, and that the globes moved in circular orbits. They were wrong, as it happens. As Johannes Kepler discovered through meticulous observation in the early 17th century, planets wander closer and further from the sun, in the geometric form of an ellipse. They travel faster when closer in, and slower when further out. An imaginary line connecting planets to the sun traces out equal areas in equal times: what we now know as conservation of angular momentum.

Beyond relativity

It wasn't until later that century that Newton explained why this happens, with his universal law of gravitation. The source of this behaviour was indeed a symmetry – the symmetry of the invisible hand of gravity, which acts equally in all directions from a massive body such as the sun.

General relativity, Einstein's much refined theory of gravity, was founded on a symmetry too, one known as the equivalence principle. This states that there is no practical difference

between a body experiencing acceleration because of gravity and one experiencing an equivalent acceleration from a different source, such as the thrust of a rocket or the spin of a centrifuge. From the equivalence principle, Einstein developed his theory that yields everything from curved space-time and an expanding universe to black holes and the prediction (still unobserved) of gravitational waves rippling through space.

Einstein's work revolutionised our view of the universe, but also spurred a great deal of interest in the role of symmetries in physical laws. Recognising Noether as an expert, in 1915 the eminent mathematicians David Hilbert and Felix Klein invited her to Göttingen, then the centre of the mathematical world – an offer, alas, which still didn't extend to any financial remuneration. Hilbert did argue forcefully for an official appointment, but Noether wasn't given even an honorary "extraordinary" professorship until 1922. In the interim, she was merely allowed to serve as a guest lecturer, unpaid, under Hilbert's name.

Weyl, also at Göttingen in the 1920s, by contrast quickly achieved a prominent professorship, despite being Noether's junior. "I was ashamed to occupy such a preferred position beside her whom I knew to be my superior as a mathematician

in many respects," he later remarked.

The indignities of Noether's circumstances did not deter her work. Almost immediately on arrival, Noether developed her eponymous theorem. It formalised the idea, intrinsic but unstated in the examples of the two theories of gravity, that symmetries provide an express route to the heart of nature's workings.

For another example, consider a puck placed on a very smooth, very large frozen lake. Wherever the puck slides, the lake is the same. Noether's theorem provides a general way of turning that statement of symmetry into a conservation law.

Conservation laws are the bread and butter of physics. They are mathematical shortcuts that allow us to compute physical quantities once and then never again. Whatever you start with, that's what you'll end up with. That is incredibly useful: think how much trickier it would be to manage your time if the number of hours in the day changed constantly and were not conserved at 24; it's bad enough twice in the year when the clocks go forward or back.

Most of the great laws of physics include some statement of conservation, implicitly or explicitly. Newton's first law of motion crudely states that "objects in motion stay in motion, and objects at rest stay at rest". That is nothing more than conservation of momentum, a consequence of the sort of spatial symmetry that governs the physics on top of our idealised frozen lake. Send a puck across the ice and, discounting friction, it will continue indefinitely. But the conservation law only holds as far as the symmetry does. A hole in

"THE INDIGNITY OF NOETHER'S CIRCUMSTANCES DID NOT DETER HER WORK"

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the ice will disturb the symmetry, causing the puck to sink to the bottom of the lake and come to rest – violating Newton's first law.

It's not always obvious what is conserved and what isn't. For a long time, it was assumed that mass couldn't be created or destroyed, but Einstein's famous relation $E=mc^2$ said otherwise. Matter can be created, if not out of thin air, then out of pure energy. In fact, although you are made of molecules that are made of protons and neutrons, those protons and neutrons are made of quarks. Quarks, as it happens, are so light that they make up only

about 1 to 2 per cent of your body mass. The rest comes from the incredible energies with which these quarks interact.

Although matter can be created from energy, energy itself in all its myriad forms adds up to a constant and permanent total. Before Noether, energy was simply assumed to be conserved, an assumption so basic that it became known in the 19th century as the first law of thermodynamics. But do the mathematics associated with Noether's theorem and it becomes plain that energy is conserved because of an even more basic symmetry: specifically, that the laws of physics aren't changing with time. If they did, energy wouldn't be conserved.

What Noether's theorem adds up to is a practical prescription for making progress in physics: identify a symmetry in the world's workings, and the associated conservation law will allow you to start meaningful calculation.

But it is also, in a sense, a statement about how the universe *should* be structured. When we look at the universe on the human scale, or even at the level of our solar system, space seems very different from a smooth lake: there are planet-sized bumps and wiggles. But take a broader picture – on the scale of hundreds of millions of light-years – and the universe appears much smoother. The assumption is that on the very largest scales, the universe is more or less the same.

As we lack the ability to travel billions of light years to beyond the observational horizon of our most powerful telescopes, this really is just an assumption, and it goes by ➤

Magic recipe

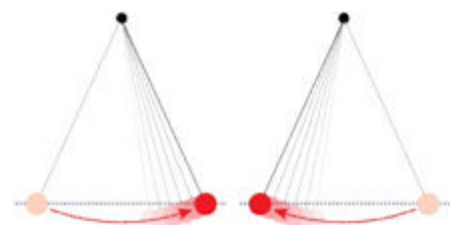
Symmetries exist everywhere in nature. Emmy Noether's theorem of 1915 provides a way to translate them into laws useful for calculations

SYMMETRY: TRANSLATION IN TIME

The basic laws of physics do not vary over time

CONSEQUENCE: Energy is conserved

However many times a pendulum swings, with no air resistance it will always reach the same height

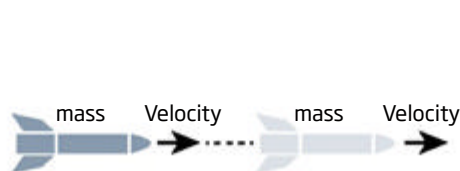


SYMMETRY: TRANSLATION IN SPACE

The laws of physics don't change when you move from one place to another

CONSEQUENCE: Momentum is conserved

A rocket flying through free space continues flying at the same speed, if no other forces act on it

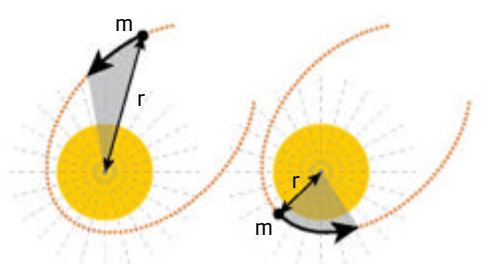


SYMMETRY: ROTATION IN SPACE

Forces such as gravity emanate equally in all directions

CONSEQUENCE: Angular momentum is conserved

Comets speed up nearer the sun. The area between their path and the sun is always the same in a set time



the name of the cosmological principle. It tells us that what we call “down” on Earth is nothing more than a consequence of the relative position of us and the rock we’re standing on. The universe has no up or down, nor a centre for that matter. Its laws don’t seem to be in any way related to where we measure them, how our measuring devices are pointed, or even when we decide to make the measurements. Through Noether’s theorem, symmetries of space and time yield conservation of energy, momentum and angular momentum everywhere, all the time (see “Magic recipe”, page 35).

But there’s much more. Symmetries in space and time might be obvious to the naked eye, yet Noether’s theorem’s true strength comes from “internal symmetries”. To the uninitiated, the standard model of particle physics is nothing more than a list of fundamental forces and particles. But it is a model of internal symmetries writ large, and it was built on Noether’s theorem.

The most familiar force it deals with is electromagnetism, which describes the current running through our power cords, the behaviour of compasses and the shock of lightning. James Clerk Maxwell is generally credited for writing down a theory that unified electricity and magnetism into one working model in the 1860s. One of its assumptions is

“WE ASSUME THE
UNIVERSE HAS NO
UP OR DOWN, NOR
A CENTRE FOR
THAT MATTER”

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that electric charge is neither created nor destroyed, an idea that goes back even further to Benjamin Franklin in the 1740s.

Noether’s theorem shows that charge conservation, too, arises from a symmetry. Fundamental particles have a property called spin, and just as position doesn’t matter on a frozen lake, what’s known as the spin’s phase

doesn’t change physical calculations. “Turn” every electron in the universe an extra degree, and neither energy nor anything else changes. What pops out, according to Noether’s mathematics, is charge conservation.

Weyl took this idea of phase symmetry a step further and supposed that every electron might be twisted by a different amount and still remain the same. Assume this and, almost by magic, all four of Maxwell’s equations emerge.

As the standard model has developed, so the symmetries of interest have become more subtle – but Noether’s theorem has been the gift that keeps on giving. It is hard to conceive, for example, that electrons, the particles that run through wires to power electronics, and neutrinos, which fly through us by the trillions every second without leaving a mark, are in some sense the same particle.

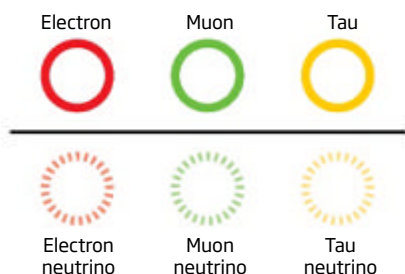
Neutrinos primarily interact through the weak force, which controls nuclear fusion in the sun. But the weak force is indifferent to whether a particle is an electron or a neutrino: switch them round, and weak interactions will be the same. This symmetry produces conservation of a quantity called weak isospin that, like electric charge, can be used to label particles and predict how they will behave (see “Hidden principles”, below).

In the 1960s, researchers found that

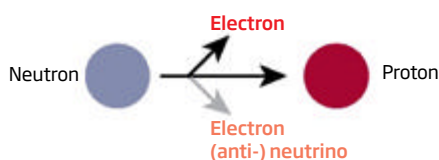
Hidden principles

The workings of the standard model of particle physics – and perhaps physics theories beyond it – are determined by some subtle symmetries

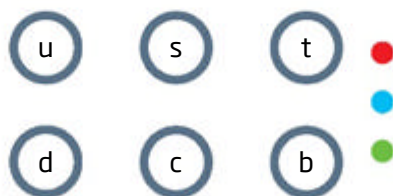
SYMMETRY: the electron and similar charged “leptons” have a neutral neutrino equivalent



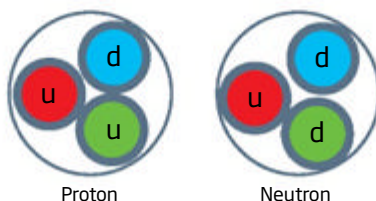
To keep the balance when electrons are emitted in processes such as beta decay, a neutrino is also produced



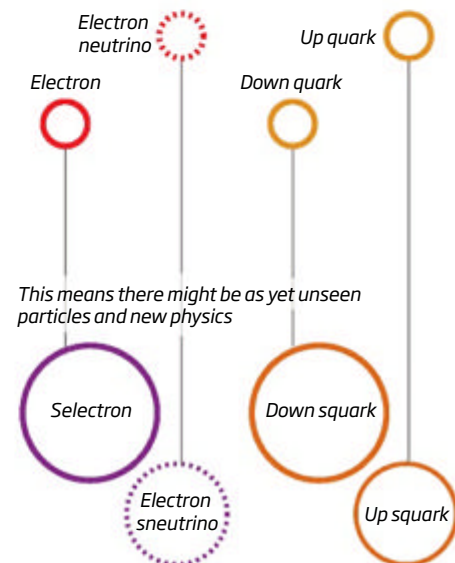
SYMMETRY: all of the six varieties of quark come in the same “colours”



Particles containing quarks, such as protons and neutrons, are made of “colour-neutral” combinations. Switch two colours and nothing changes



SYMMETRY: according to the unproven theory of supersymmetry, every lepton and quark should have a heavier “sparticle” equivalent



This means there might be as yet unseen particles and new physics

electromagnetism and the weak force could in fact be generated by a single symmetry, in what became known as the electroweak theory, a keystone of the standard model. “Breaking” that symmetry into two separate pieces produced a bunch of new interactions, along with the prediction of a new particle – what we now know as the Higgs boson. We waited a half-century for the confirmation of this prediction, which stemmed directly from the sort of considerations Noether’s theorem introduced into physics. It came, eventually, with the discovery of the Higgs at CERN’s Large Hadron Collider in 2012.

The other pillar of the standard model is the strong interaction, which holds individual protons and neutrons together. The quarks that make up these particles are labelled with one of three “colours”: red, green and blue. Shift all the colours by one, and all strong interactions will remain exactly the same.

Colour symmetry leads – in what might at first seem to be a tautology – to conservation of colour. Since that idea was first introduced, work on the nature of the strong force has found that all particles in nature exist in states without colour – “white”, effectively. Protons and neutrons are examples of particles called baryons that consist of three quarks, one red, one blue, one green. The universe as a whole seems to be colourless, just as it is electrically neutral, and the symmetry of the strong force is what makes particles like protons and neutrons possible in the first place.

The thrill of the chase

Physics is now at the point where new theories are built on the assumption of a fundamental symmetry, and an informed guess about what that symmetry might be. Unification is a holy grail of physics: the drive to develop theories that can describe everything in just a few, albeit possibly outstandingly difficult, equations. What sort of symmetry might unify the electroweak and strong forces we do not yet know, but the search for such a “grand unified theory” is an active area of physical endeavour. A good grand unified theory might predict where all of the protons and neutrons in the universe come from. The total number of these baryons seems to be conserved too. Experimentally, we’ve tried to see if protons, the lightest of the baryons, can decay into anything. If we ever observe this we’ll have some idea as to whether baryon number is really conserved, a key clue to grand unified theory.

Of particular interest as we look beyond the

Emmy Noether remains largely unknown, despite her seminal work



THE GRANGER COLLECTION/TOPPHOTO

standard model is supersymmetry, a model at the heart of many fledgling grand unified theories. Supersymmetry is based on unifying the two major groups of fundamental particles: fermions (the particles that make up matter such as electrons and quarks), and bosons (including the photon, the Higgs and other particles governing forces). It supposes that ultimately every fermion has a partner boson and vice-versa: hypothetical exotics such as “selectrons” and “higgsinos”. At high enough energies, the supposition is that an electron and a selectron behave the same way, just as neutrinos and electrons behave identically under the weak force.

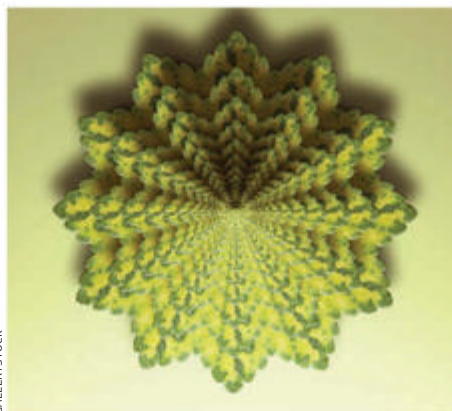
Supersymmetry neatly solves many problems of the standard model, as well as providing a motivation for why particles have the masses that they do. In principle, that is.

The Large Hadron Collider is hard at work looking for signatures of supersymmetry, but the lack of any success so far suggests we’re barking up the wrong tree.

Even further away is the goal of folding gravity, that original object of symmetric study, and the forces covered by the standard model into a “theory of everything”. Indeed, physics is still far away from a final resolution. But in the thrill of the chase for better answers, it is studying symmetries that will guide us along the way – and it is Noether’s theorem that will magic useful physical insights from that.

Compared with this stellar legacy, the rest of Noether’s biography is kind of a downer. She left Germany to escape the Nazis in 1933 and came to Bryn Mawr College in Pennsylvania, dying of complications from cancer surgery two years later. As Einstein wrote after her death, “Fräulein Noether was the most significant creative mathematical genius thus far produced since the higher education of women began”. Others might suggest the second part of that sentence is superfluous. Mathematicians do revere her, yet despite laying the groundwork for much of modern physics, physicists tend to gloss over her contributions. A century on, it’s time she had the recognition a genius of her stature deserves. ■

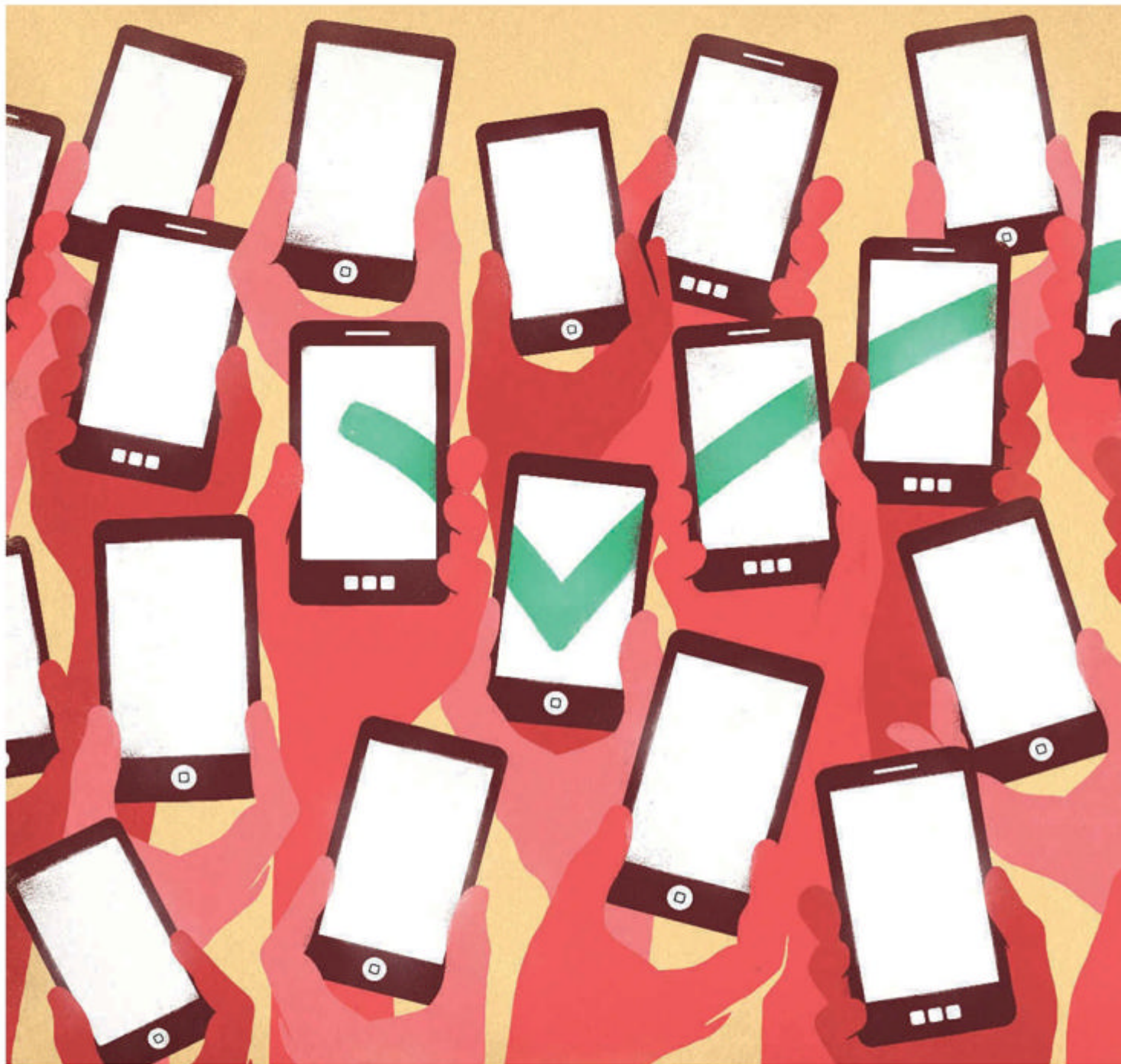
Dave Goldberg is a physicist at the Drexel University in Philadelphia, Pennsylvania, and the author of a book about symmetry, *The Universe in the Rearview Mirror* (Dutton, 2013)



GALLERYSTOCK

We the people

Decisions can now be genuinely democratic, thanks to the internet. Is this the end for politicians, wonders **Niall Firth**





SEBASTIEN THIBAUT

THE system's broken. Nothing changes. All politicians are the same. Why vote? It's a popular refrain, particularly among the young. People feel cut off from the political process and unrepresented by the political elite. Just 16 per cent of Britons say they trust politicians – that's even worse than bankers. "We're living through a crisis of mainstream politics," says Carl Miller at London-based think tank Demos.

Voter turnout has been steadily declining in established democracies in Europe, Latin America and the US for the past few decades. Turnout for the last three general elections in the UK, for example, has been the lowest since the 1940s. Comedian-turned-activist Russell Brand calls for revolution: "I feel it is a far more potent political act to completely renounce the current paradigm." With plenty of exposure in mainstream media, his message is proving seductive.

What has gone wrong? Ask people in the street and the answer is likely to be different each time. But most griping tends to boil down to distrust and a sense that governance is something other people do on your behalf, whether or not they have your support.

It wasn't always like this, says Miller. We used to get involved. "Political parties have lost millions of members since the 1950s and underlying this is an enormous deficit of trust." At the same time, however, there has been a rise in the number of protest movements around the world – a surge in the number of people voicing their opinions on the streets, in online petitions and via Facebook campaigns.

Do we simply need to upgrade our political system? "We should see democracy as an evolution over time," says Joonas Pekkanen of Open Ministry, a government-backed

"The internet breaks down the last justifications for professional politicians"

organisation in Helsinki, Finland, which promotes a more participatory democracy. "If we were to start from scratch we would never come up with the system we currently have."

So, if there's a better way, what is it? For hundreds of thousands of people around the world the answer is simple – use the internet. New online tools are revitalising old democratic practices, bypassing the political middlemen and even offering the prospect of a world without politicians at all. As the UK

gets ready for the ballot box once more, will politics get the upgrade it deserves? Or are we better off sticking with what we've got?

For some, the birth of the internet spelled the end for politicians. Digital rights activist Aaron Swartz, who killed himself in 2013, believed it could reinvent democracy. "As the internet breaks down the last justifications for a professional class of politicians, it also builds up the tools for replacing them," he wrote.

Many others think this way too. The most radical means of flipping traditional politics on its head is liquid democracy (see "Four flavours of democracy", page 41). While the idea is old – it first popped up in an 1884 article by Lewis Carroll – it is only in the past few years that the internet has made it possible for the system to function as it was originally intended.

Have my vote

The basic concept is that every voter has a mandate to exercise as they see fit. The mandate is transferable, so voters can decide to pass theirs on to someone they trust. Feel uncertain about the pros and cons of taxation but have a friend who's an economics professor? Hand them your mandate for that one vote – or even all future votes on economic issues. That designated person can then opt to cast their own vote and yours – or hand them on again to someone else who can vote for both of you. If you feel strongly about a particular issue later on you can take back your mandate and vote directly.

In theory, it is the perfect balance of direct and representative democracy, one that ebbs and flows with the topic. It has a number of obvious advantages over today's system, says Rouven Brües of the Liquid Democracy Association in Berlin, Germany. At the moment, citizens can only have an impact on politics every few years. "A lot can happen in four years and I'm not able to change my vote or take it back if I see that someone is not doing what she promised as my representative," he says. Most traditional parties also do not reflect the opinions of large swathes of the electorate.

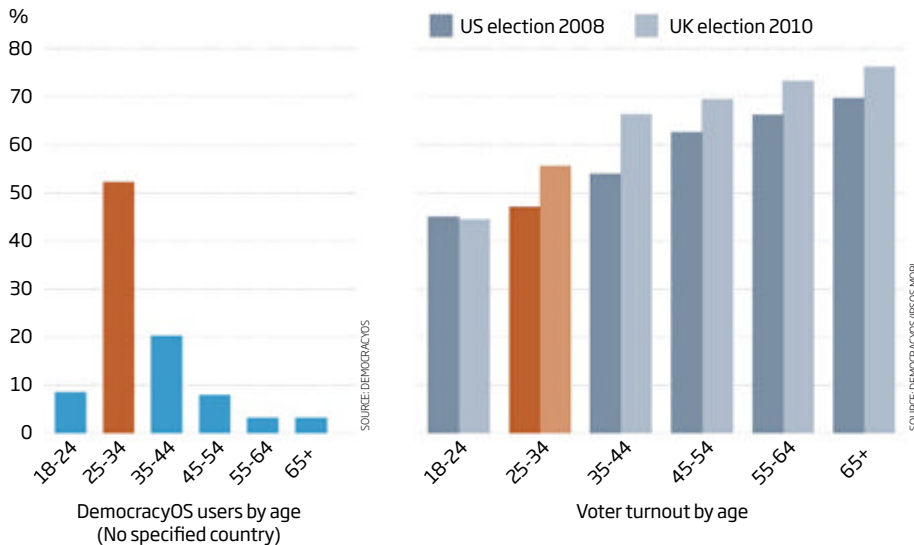
Could it ever scale up to replace the existing system? Germany's Pirate Party popularised the concept when it started using software called Liquid Feedback, a platform that supports the process of liquid democracy, in all of its internal decision-making. But they ran into a few problems.

One of them was who receives the mandate. "What's the difference between a politician and someone who receives



Youthful enthusiasm

People in the 25-34 age group are among the least likely to engage with mainstream politics. They are also the most likely to use DemocracyOS, an app that lets users debate and vote on proposals put before politicians



200,000 delegated votes?” asks Brües. Such “super-delegates” became a major issue for the Pirate Party as people who were simply better known than anyone else collected the most mandates. “The network effect means delegated votes go to people who already have lots,” says Brües.

But there is an even more fundamental issue. Because the system does not differentiate between voters and representatives, every vote has to be recorded, open and transparent. That makes a secret ballot impossible – one of the bedrocks of modern democracy. This is more than just a wrinkle – even Liquid Feedback’s most passionate supporters accept the lack of secrecy makes it unsuitable in most situations.

Deliberative democracy is another option. Championed by James Fishkin at Stanford University since the 1980s, the focus is on how we can become more involved in deciding the way our lives are run, rather than changing the way we vote. “Democracy should be about connecting policy to the will of the people,” says Fishkin. That means judging what the people really want – and competitive elections do not guarantee that, he says.

In the past few years, so-called citizen assemblies have blossomed. The G1000 project in Belgium picked 1000 citizens who gathered together to brainstorm new public policies. The best ideas were then taken forward by a smaller group. Similar events have taken place elsewhere, such as the

We The Citizens project in Ireland in 2011.

A number of cities around the world, particularly in Brazil, practise a form of deliberative democracy known as participatory budgeting, which gives people a direct say in how a percentage of their council budget is spent. This is one of the most widespread and fastest growing democratic practices of the 21st century, says Matt Leighninger of the Deliberative Democracy Consortium, an international network of researchers based in Washington DC.

“People are happier paying taxes when they have a say in how the money is spent”

There is evidence that people are happier about paying taxes when they live in areas where they have a say in how public money is spent. Other studies have shown that participatory budgeting makes councils spend more efficiently, completing more of their planned building works, for example.

Now deliberative democracy is moving online, inviting even more people to wrestle with difficult topics and reach a consensus. It is having an impact, too. Finland has just passed its first crowdsourced bill. The Finnish model was set up by Open Ministry and has allowed hundreds of people to collaborate on policy documents at the same time, making

amendments or tweaking wording until agreement is reached – much like the evolution of a Wikipedia article.

Once a policy attracts 50,000 backers, parliament votes on it. The Finnish parliament passed a bill on same-sex marriage in November – the first legislation to be drafted in this way. However, it is the only one of nine Open Ministry bills to be passed so far – and would arguably have done so anyway.

Collaborative drafting can be complex. Open Ministry typically has more than 100 working groups to develop the various proposals. Managing this via the likes of Facebook quickly gets unwieldy. But a new breed of dedicated software is helping to streamline the process.

One such tool is Adhocracy, built by Brües and colleagues at Liquid Democracy. It lets large numbers of people collaborate on policy documents, make proposals and reach agreement on difficult decisions without calling in elected officials. You can start or contribute to discussions and vote for or against proposals.

Another is a website called Loomio, which again supports crowd decision-making. Springing out of the Occupy movement of 2011, more than 65,000 people in 80 countries are trying Loomio, and it has been translated into 31 languages. It is the tool of choice for more than 25,000 people in Spain alone, many of them part of the grassroots base of the Podemos political movement. Debated topics range from green energy to artists’ incomes. More than 23,000 decisions have been reached in 59,000 discussions, says Loomio’s founder Ben Knight. “That’s a lot of people engaging in deliberation.”

A new generation of politically active young people has sprung up in response to the austerity measures in Europe that followed the financial crisis, says Francesca Bria at innovation-fostering charity Nesta in London. She leads a pan-European project called D-Cent or Decentralised Citizens Engagement Technologies, which brings together a consortium of activists and hackers – including Open Ministry – to devise tools that can shake up democratic processes.

“Outside government, there’s huge dissatisfaction with the way representative democracy is – or isn’t – functioning,” says Knight. For Knight, the large number of protest movements around the world send the same basic message. “People want to have more of a say in the decisions that affect their lives.”

With all the buzz, it is no wonder mainstream

politicians are getting in on the act, too. Miller and his team at Demos worked alongside Wikimedia – the organisation that runs Wikipedia – to crowdsource a submission to the UK Speaker's Commission on Digital Democracy, which was published in January this year. The commission has recommended that the next parliament should include a “cyber chamber” that would let members of the public take part in debates held in Westminster Hall. If the experiment is deemed successful by the end of the next parliament then debates in the House of Commons itself will also include cyber chambers.

But will any of this make a difference? Will Bria's generation be the one that dispenses with politicians, as Schwartz predicted? Bria does not think so. “Could we replace politicians? That's the fetishism of Silicon Valley,” she says. “Software on its own is never the answer.” Instead, Bria points to Podemos, which has risen to become the top-polling political party in Spain. Podemos uses a mix of offline citizen assemblies and online forums – including Reddit – to expand its supporter base and let party members debate policy proposals. “Podemos will show how political parties can function in the 21st century,” says Bria.

Argentina's Net Party was also set up on the back of such participatory ideals. It was founded by the team of coders and political

FOUR FLAVOURS OF DEMOCRACY

DIRECT DEMOCRACY

Citizens vote on policy decisions directly. This was the approach used in ancient Athens, one of the birthplaces of democracy, and is still used in parts of Switzerland today. A referendum is a one-off example of direct democracy in action.

REPRESENTATIVE DEMOCRACY

Citizens vote for representatives who make decisions on their behalf. This approach is used in most modern democracies.

LIQUID DEMOCRACY

Citizens have the option of delegating their mandate on a per-vote basis to individuals who may be better placed or informed on a particular issue. In turn, delegated individuals can choose to pass mandates on to others. Citizens can take back their mandate at any time.

DELIBERATIVE DEMOCRACY

A form of direct democracy in which citizens participate in policy debates as part of a consensus-building process.

scientists behind DemocracyOS – software used by Podemos and the Mexican government to support liquid democracy. The party's key principle is that candidates must pledge to vote in parliament exactly as its supporters have voted online. Platforms like DemocracyOS are particularly popular among the young, a demographic more likely to be disengaged from mainstream politics (see charts, left).

Popular demand

Greater participation by the public is a noble aim but will it work any better than conventional politics? Populism does not necessarily lead to workable outcomes. For example, the left-wing populist party Syriza recently rose to power in Greece thanks to the popular appeal of its anti-austerity policies. But it is not clear whether the party can lead the country out of its current crisis.

Fishkin thinks that listening to the will of the people almost always ends up in better policies, but the method used to divine their intentions is crucial. “Populism has a long history of negative uses. The referendum was used by Napoleon and Mussolini,” he says.

Even so, Pekkanen and others are adamant that only change can restore public faith in our political institutions. “Reinventing our decision-making processes – and leveraging the power of the internet in doing so – is the only hope of regaining the legitimacy of our current democratic systems,” he says.

But a referendum for every decision – voting *X Factor* style – might be unrealistic. Much of public policy deals with boring issues that would be tough to sell to people. It's all about balance, says Leighninger. Perhaps only 10 per cent of decisions should be opened up to public vote, he says. “But if we pick the right 10 per cent, and the processes for making those are done well, it will have great benefits.”

The trick is to pick the most representative cross-section of decision-makers, says Tiago Peixoto, who leads the digital engagement unit at the World Bank. “We need to start thinking about democracy as how best to leverage the knowledge of the population,” he says. “Diversity is what you need for good problem-solving.”

“When people have meaningful, productive roles in making public decisions and solving public problems, we get smarter, more equitable, more broadly supported public policies,” says Leighninger. ■

A mix of offline and online debate can boost public engagement with political parties



DAVID BAKOS/GETTY IMAGES

Niall Firth is news editor at *New Scientist*

Some flowers lace their nectar with toxins.
Why risk poisoning their pollinators, wonders
Stephanie Pain

Sweet deceit



IN 401 BC, 10,000 Greek mercenaries were marching home from war against the king of Persia. Passing through Colchis, on the eastern side of the Black Sea, they feasted on honey stolen from beehives dotted around the countryside. Soon thousands had fallen into a stupor. The historian and soldier Xenophon describes them acting like intoxicated madmen, as if under a spell. As strangers to the region, they knew nothing of the effects of the “mad honey” made by local bees.

The men recovered within a few days, but others were not so lucky. In 65 BC, troops led by the great Roman general Pompey against King Mithridates VI of Pontus, also on the Black Sea coast, lay weak and dazed after eating honeycombs strategically placed along their route by the enemy – and were slaughtered. Mad honey had become a chemical weapon, and one that was to be used to terrible effect in this much-disputed part of the world. In 946, allies of the Empress (later Saint) Olga of Kiev tricked her Russian enemies into drinking mead made from mad honey, and then reportedly massacred 5000

stupefied men. Ivan the Great’s forces adopted a similar strategy in 1489. They left vast vats of toxin-spiked mead in their camp, returning later to wipe out the 10,000 Tatar troops who had stopped to drink it. Reports of “mad honey disease” still surface regularly, although it is rarely fatal.

Mad honey owes its awful powers to toxin-laden nectar. This is a far cry from the ancient Greek notion of nectar as the food of the gods, a golden potion that brought immortality to mere mortals who dared to drink it. But even in ancient times, some knew that nectar had a sinister side. In the first century AD, the great Roman naturalist Pliny identified the nectar of the common rhododendron (*Rhododendron ponticum*) as the source of mad honey, delicious but dangerous in the hands of those who knew its powers. Today, many dozens of plant species are known to have toxins in their nectar. Plants produce nectar to reward pollinators, so why risk repelling or even killing the animals that ensure their survival? Only now are we beginning to understand the paradox and discover just how cleverly plants manipulate pollinators for their own ends.

Nectar used to be thought of as little more than sugar-water, but closer scrutiny has revealed many more ingredients. These include an array of potentially harmful compounds: alkaloids, terpenes, iridoid glycosides, phenol-based molecules and more. Such chemicals are generally linked to plant defences, and are typically found in roots, leaves, stems and seeds. Their presence in low doses in nectar poses one of botany’s strangest

puzzles. Why are they there? Do they simply leak into nectar as they travel around the plant, or do they have a purpose?

From the start, ecologists suspected that the toxins somehow improve a plant’s reproductive prospects, and it looks as if they might be right. “Even if the toxins got there through ‘leakage’, once they were there it seemed likely plants would press them into service,” says Phil Stevenson, a plant chemist at the Royal Botanic Gardens at Kew, London. “There’s now increasing evidence that plants control what goes into their nectar – and how much. That suggests these compounds are there for good reasons.”

Take caffeine, one of the most familiar of plant alkaloids. Coffee-drinkers are well aware of its effects: a morning cup sharpens us up, a night-time cup keeps us awake – and too much caffeine causes shakes and palpitations. What might caffeine-spiked nectar do to an insect?

At least 15 genera of plants contain caffeine, primarily as a chemical defence against insects, or so it was thought. Caffeine tastes bitter to insects, and bees are no exception; they find it repellent. But this doesn’t deter them from visiting the flowers of coffee and citrus plants, the nectar of which has been found to contain caffeine. It turns out that the caffeine is present at levels too low for bees to taste, as Stevenson and neurophysiologist ➤



NATURE'S POISONED CHALICE

Almost 90 per cent of flowering plants are pollinated by animals, which are rewarded for their services with sugary nectar. With the world's pollinators in alarming decline, how worried should we be to discover that a wide variety of plants lace their nectar with poisons?

The consensus is that pollinators are disappearing as a result of a combination of stresses – diseases, parasites, inadequate nutrition and synthetic pesticides such as neonicotinoids, which end up in nectar and pollen. “Until now, the role of nectar toxins has been overlooked,” says Phil Stevenson at the Royal Botanic Gardens at Kew, London. “But added to other sublethal effects, such as poor nutrition, they could be the tipping point.”

There have been many anecdotal reports of pollinators dying after feeding from certain flowers, and lab studies have revealed that bees fed nectar toxins can suffer a range of harmful effects, from reduced mobility to reproductive failure and lower rates of survival. In natural landscapes, however, nasty nectar probably poses less of a hazard. “Just as bees learn to prefer flowers that offer the best reward, they can also learn to avoid flowers with toxic nectar,” says Jeri Wright at Newcastle University, UK. If they can taste toxins, they reject the food. “But they don’t just have to rely on taste,” she says. “We’ve found they are able to learn what made them feel unwell, and use associated cues – such as a flower’s odour – to avoid it next time.”

Toxic nectar is more of a threat in landscapes where a single crop or invasive plant that produces nasty nectar covers vast areas. Then, a pollinator’s options are limited. “If bees feed on toxic nectar, they might be poisoned. If they avoid it but there’s little else around, then they’ll suffer from inadequate nutrition. Either way, that could have a severe impact on their colony,” says Stevenson.

So, how to avoid adding to pollinators’ many problems? “We can try to manage the landscape in ways that make it better for pollinators,” says Stevenson. “The most obvious way is to ensure there is a wide enough choice of flowers to satisfy the needs of a diversity of bees and other pollinators.”



Jeri Wright at the University of Newcastle, UK, recently revealed. Yet when offered a choice of nectar with or without a dash of caffeine, bees prefer it with. Wright suspected that caffeine acts as a drug, influencing a bee’s mind in much the same way it does ours. She was right.

Mind-bending nectar

In the lab, Wright trained bees to associate nectar with a particular floral scent. When she added caffeine to a drop of nectar, twice as many bees remembered the scent three days later. Closer investigation suggests that caffeine produces this dramatic improvement in long-term memory by intensifying how the bee’s brain reacts to information from its antennae, where smells are detected (*Science*, vol 339, p 1202).

If bees remember which scent or colour indicates good food, they are more likely to return to the same sort of flowers, bringing other members of the colony with them. Plants that use caffeine to manipulate bees’ minds in this way should benefit from the greater loyalty of their pollinators. The jury is still out on whether caffeine-laced nectar ultimately increases a plant’s reproductive success, but it’s looking increasingly likely. James Thomson of the University of Toronto, Canada, recently reported the results of trials with free-flying bees foraging from artificial flowers endowed with fake pollen and fake nectar. Flowers with caffeine-laced nectar received significantly more pollen (*Arthropod-Plant Interactions*, vol 9, p 1).

Messing with a bee’s mind to encourage fidelity isn’t the only way in which plants

harness their toxic assets to improve the odds of pollination. Tobacco plants enhance their prospects by altering the foraging behaviour of pollinators – with the help of nicotine.

Nicotine is a highly toxic alkaloid made by tobacco plants to ward off caterpillars, leafhoppers and other enemies. Danny Kessler and Ian Baldwin at the Max Planck Institute for Chemical Ecology in Jena, Germany, have spent many years studying *Nicotiana attenuata*, a wild tobacco from the Mojave desert in the US Southwest. They found that bitter-tasting nicotine repels carpenter bees, visitors that would otherwise consume nectar without pollinating the flowers. They also found that the hawkmoths and hummingbirds that pollinate this species find the taste equally repellent. That, however, turns out to work in the plant’s favour (*Science*, vol 321, p 1200).

Along with nicotine, this wild tobacco spikes its nectar with benzylacetone, a powerfully attractive scent molecule. The scent lures pollinators; the nicotine cuts their visits short, leaving more nectar in the flower to attract new visitors. This chemical carrot-and-stick strategy results not just in the production of more seeds but also in greater movement of pollen between flowers on different plants. The result is a healthy mixing of genes and a greater capacity to survive challenges such as a changing environment (*The Plant Journal*, vol 71, p 529).

Flowering plants have famously evolved ingenious, often extravagant, features to enlist the services of specialist pollinators. Could this explain the nectar of the common rhododendron, the source of mad honey?



Bumblebees thrive on the nerve toxins in rhododendron nectar

Rhododendron ponticum is native to southern Spain and Portugal, and across Turkey to Georgia, but it's in Ireland that researchers are unravelling the role of the nectar toxins that knocked out ancient armies. These belong to a group of nerve poisons called grayanotoxins. *R. ponticum* was introduced to Ireland in the late 18th century, probably from Spain, and is now naturalised over large swathes of the countryside, where it is a serious pest. Its flowers are visited almost exclusively by bumblebees, with occasional visits from solitary bees, flies, ants and wasps. "You almost never see honeybees in badly infested areas," says ecologist Jane Stout at Trinity College Dublin in Ireland. She teamed up with Stevenson and Wright to find out why.

Tests with captive bees showed that grayanotoxins have dramatically different effects on different types of bee. "They have no apparent effect on worker bumblebees," says Stout. "Mining bees show short-term symptoms of malaise. They lie on their backs with their legs in the air but recover later. But honeybees die within hours." In honeybees – and humans – grayanotoxins hold open the sodium channels present in all nerve and muscle cells, so that neurons keep firing until they are fatigued. In the bees, this leads to palpitations, paralysis and death. "We don't know why this doesn't happen in bumblebees," says Wright. "Like any other drug, some animals are more susceptible than others."

Poisonous partnership

Stout suspects that grayanotoxins have helped to forge a partnership between rhododendrons and bumblebees. Rhododendron flowers are large, and conceal their nectar in a tubular fold in the back petal. "Bumblebees make better pollinators because they are big and hairy and pick up pollen easily. They tend not to groom off the pollen, so it gets transferred to the next flower they visit," she says. But if *R. ponticum* selectively courts bumblebees by offering near-exclusive access to its nectar, how to explain mad honey? Stout suggests that honeybees living within the rhododendron's native range have had time to adapt to its toxic nectar. "The subspecies of honeybee that makes mad honey in Turkey has probably evolved to resist the toxins in a similar way to the bumblebees."

Pollinators visit flowers for food, but what if nectar offers them something besides nutrients? New research suggests that some flowers can be pharmacies as well as food stores, and that some insects might seek out

Hummingbirds are soon repelled by nicotine in nectar



DANNY KESSLER

"Some insects might seek out toxic nectar for its medicinal properties"

toxic nectar for its medicinal properties.

Many plants produce antimicrobial compounds. In nectar, these probably help suppress microorganisms that consume sugar, so preserving it for pollinators, but they could also stave off disease. "Flowers are like airports, a hub of intense activity. As insects fly from flower to flower, they pick up and deposit pathogens, which can then infect the plant," says Lynn Adler at the University of Massachusetts, Amherst. Pollinators, too, are exposed to these parasites and pathogens, and Adler suspects some nectar toxins could reduce the spread of insect diseases.

Until recently, the idea that chemicals in nectar could "treat" insect diseases was little more than speculation. A single study showed that gelsemine, an alkaloid in the nectar of an American vine called yellow jessamine, has a therapeutic effect on bumblebees. In worker bumblebees infected with the common gut parasite *Crithidia bombi*, gelsemine reduced the number of parasites by as much as 65 per cent. The parasite, spread via faeces deposited on flowers and in the nest, shortens the life of both individual bees and colonies.

Adler and her colleagues Becky Irwin and Leif Richardson at Dartmouth College in Hanover, New Hampshire, decided to see whether other nectar toxins might have a similar medicinal effect. Testing eight of these

on bumblebees, they found that all reduced levels of infection. Four produced dramatic results, reducing the number of parasites by as much as 81 per cent (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2014.2471). "By reducing parasite loads, these toxins could play an important role in reducing transmission between bees and between colonies," says Adler.

But although these studies suggest toxic nectar benefits some plants and pollinators, it could have a darker side. Some pollinators feed on nasty nectar with no ill effects, but other insects may be harmed or even killed. "What's one bee species' medicine may be another bee's toxin," says Adler. As the list of species with toxic nectar grows, ecologists are wondering whether it could be contributing to the global decline in pollinators (see "Nature's poisoned chalice", left).

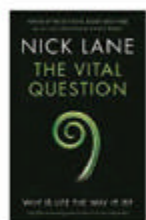
The ancients may have known enough about nasty nectar to gain an edge over their enemies, but we are still a long way from understanding its role in nature. One thing seems clear, however. If plants harness their noxious assets to medicate, manipulate and mess with the minds of the animals they depend on, then they probably have plenty more surprises in store. ■

Stephanie Pain is a consultant for *New Scientist*

The way we are...

A grand vision of how life began and evolved spawns a book full of surprises, finds **Michael Le Page**

The Vital Question: Why is life the way it is? by Nick Lane, Profile Books, £25



FOR billions of years after they first arose, living cells stayed simple. But as oxygen levels climbed, these cells began to exploit it to get

more energy. Many began to evolve in the same direction, becoming larger and more complex. Some grouped together to form animals, plants, fungi and so on. These complex cells may look similar, but their genes show they evolved independently on many occasions.

Except this is exactly what did not happen. Complex cells evolved just once. All those countless trillions of simple cells evolving away for billions of years, and yet they stayed simple, with just a single exception.

This is very peculiar when you think about it. For biologist and writer Nick Lane, it is one of the really big mysteries about life he looks at. Others include: how did life first evolve? Why do we age? What is life like on other planets? Why did sex evolve? Why are there usually two sexes? How do new species arise? Why do up to 40 per cent of human embryos die before women even realise they are pregnant? How did we come to live twice as long as our great ape cousins?

These may seem like unrelated questions, but for Lane they are all intimately and inextricably linked. With the help of his long-

term collaborator Bill Martin and others, Lane has been developing a grand vision of where and how life began, and why it evolved in the way it did. What's more, he thinks the "gene-jocks" will never answer these questions by studying genomes and the like. Instead, we need to focus on what drives life: energy.

Living cells are powered by a totally unexpected process. The energy from food is used to pump protons across a membrane to build up an electrochemical gradient. This gradient drives the machinery of life, like water from a dam driving a turbine.

And Lane argues that life has been powered by proton gradients from the very beginning. Forget all those primordial soups or "warm ponds": only the natural proton gradients found in

"Forget primordial soups or 'warm ponds': only undersea vents could provide what life requires"

undersea alkaline hydrothermal vents could have provided the continuous flux of carbon and energy that life requires. These vents may be common on rocky planets so, if this reasoning is

correct, simple cells should be too.

It's the next step that is tricky. To become more complex, cells need more membrane to provide more energy. But the larger the area of membrane, the harder it is to keep control of the proton gradient – and losing control means death. So cells stayed simple. "There is no innate or universal trajectory towards complex life," Lane writes.

Not, at least, until something extraordinary happened: one kind of simple cell somehow started living inside another. Eventually, the first cell turned into the self-contained energy-



Our ancient origins may determine our lifespan

producing structures we call mitochondria. This Russian-doll arrangement meant cells could get more energy simply by making more mitochondria, allowing them to become much larger and more complex.

But learning to live together was far from easy. The first complex cells were forced to evolve features such as sexual reproduction and DNA wrapped up in a membrane to survive. In other words, the acquisition of mitochondria wasn't just necessary for cells to become complex, it shaped their entire nature – and it still does. Our lifespans are determined by our mitochondria, Lane argues, but not because they produce free radicals, as we once thought.

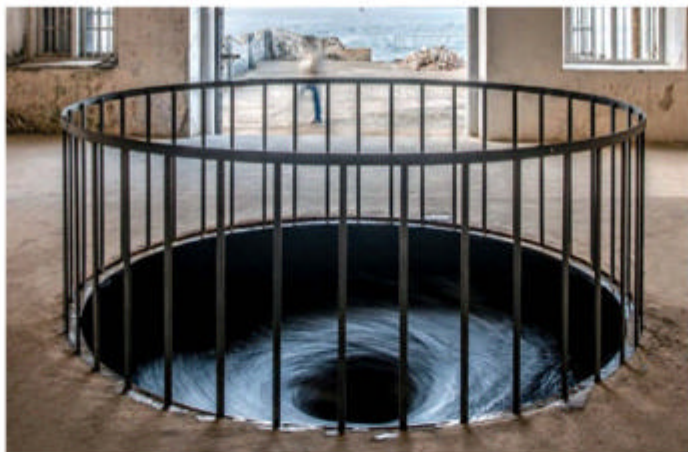
It sometimes seems that there are few big ideas in biology any more, that it's all about specialists crunching data. But this is a book of vast scope and ambition, brimming with bold and important ideas. I do hope some of them are wrong, because it's disappointing to think that alien life consists mostly of slime, or that it will be very difficult to extend our lifespans beyond about 120 years.

The arguments are powerful and persuasive, however, and many of the ideas are testable. Lane is recreating the conditions

“The ‘gene-jocks’ will never answer questions about life by studying genomes and the like, says Lane”

found in alkaline vents in his lab, for instance, to see if they really can drive the kind of reactions life requires – and so far he reports positive results.

If you're interested in life, you should read this book. It's not the easiest, despite Lane's efforts, but it does tell an incredible, epic story. That story starts with the dawn of life itself and takes us right up to the present day, to explain why we are the way we are. ■



Descension is a whirlpool of an artwork with a void at its heart

pretty sure that everything we consider to be real is illusory, or has an illusory element. From a psychological point of view, it matters more how we perceive something than how we measure it. After all, objectively speaking, colour doesn't even exist. So that's the game. Keep your balance. Whenever subjectivity and objectivity are opposed, never come down on either side.

I've always been fascinated by raw pigment, which is at once a colour – a pure, psychological idea – and a real substance. It has this otherness you can't quite point at. My latest works are made with silicone, very red, and very visceral. I work with red a lot. The way the eye perceives the colour means that red is seen as much darker than black or blue.

And I've always been deeply interested in geometry. I've put some pieces into motion to get at forms I can't produce by any other method. *Descension*, for example, is a whirlpool that produces a natural parabola. It took 20 years to get it to work because it needs to be built at a certain scale, and to spin at a certain rate. What surprised me, once I'd achieved those parabolic curves, was what happened at the bottom of the pool. A void opened up, a form I never expected, for all the world as though this thing was boring its way to the centre of the Earth.

So art and science do sit naturally quite close to each other. But making a statement of that sort in a piece of art is just going to get in the way. Science is apparently rational and art, perhaps, more confused. But they both start out as experimental processes. A poetic purpose is every bit as real as an apparently scientific one. There's objectivity in art, just as much as there's subjectivity in science. ■

Taken from a conversation with Liz Else and Simon Ings

Space, voids, ghosts

With a visceral, disturbing show in London, sculptor **Anish Kapoor** talks to Culture Lab

Untitled by Anish Kapoor is at the Lisson Gallery, London, until 9 May

I HAVE said this over and over again: you make what you make, and you put it in front of yourself first of all. If I started off with some big message for the world, it would keep getting in the way.

There is an emotional world and an objective world, and the two mesh. Thirty years ago I began working with the idea that for every material thing, there's a non-material thing alongside it – sometimes poetic, sometimes phenomenological.

I once made a stone chamber and painted it a very dark blue. Thanks to the way the eye deals with the colour's short wavelength, if you look inside the chamber it's as though this stone thing had a non-thing inside it. The cavity becomes an object. You get an effect like that when you look at a polished concave surface. The eye wants to fill the hollow with a sort of convex ghost.

I've been interested in what I call “void works” for many years: applying deep, dark colour to mostly concave forms so the space and object are confused. This led

me to Vantablack, a superblack made from carbon nanotubes. It's extraordinary – the light gets in and is not able to get out. Indeed, Vantablack absorbs all but 0.035 per cent of visual light.

The discovery of a new material like this opens up incredible possibilities. I love the idea that one could walk into a room that isn't dark and at the same time isn't there. You could have lights on, but the room wouldn't be there. There's something magical about that. It's that wonderful, liminal moment between wonder and fear – that's what I aim for.

I don't mind too much when people call me an illusionist. I'm



ANISH KAPOOR 2015, DESCENSION, KOCHI-MUZIRIS BIENNALE

STEFAN WERMUTH/REUTERS

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Candidates are sought to fill a scientist position in Shell's Biofuels Research and Development program. The program is focused on delivering Next Generation Biofuels into the market, primarily from ligno-cellulosic feedstocks, by both biological and thermochemical routes.

Role Accountabilities

The role will be based in Shell's Projects & Technology Group, located in the Shell Technology Center, Houston, Texas. The successful candidate will work within Shell's in-house Microbial Biofuels team, scaling-up Shell's proprietary ligno-cellulosic biofuel process from the bench to production scale. The challenges in such a process range from soil carbon and ecosystem services analysis, through enzyme hydrolysis, solid and liquid phase fermentation, to molecular microbiological transformations.

Potential candidates will be engaged in a range of activities such as: ecosystem service modelling, molecular transformation, microbial pathway evolution, enzyme hydrolysis, novel fermentation, and organism research.

Responsibilities will include: design and implementation of experimental programs aimed at producing commercially viable biofuels from micro-organisms, taking into account a wide range of contributory factors; and identifying opportunities and engaging with the development of commercial plans.

Candidates are expected to have excellent intellectual and analytical ability, the enthusiasm to progress their insights, strong teamwork and leadership skills, as well as the ability to broaden outside of their area of expertise. The successful candidate will be expected to work with Shell engineers globally, as well as with external partners.

Required Qualifications/Skills

Ideally, the successful candidate will have a PhD (or be in their final year/ write-up of a PhD) in one of the following areas, or a related field:

- Microbiology
- Biochemistry
- Environmental Microbiology

They will have demonstrated a willingness to learn and apply cross-discipline approaches to solving problems, and be happy working in a tight-knit team.

Experience in one or more of the following areas would be a distinct advantage:

- Soil carbon pathways and sequestration
- Metabolic pathway improvement via transformation
- Enzyme hydrolysis
- Solid or liquid fermentation (batch or continuous flow at pilot scale)

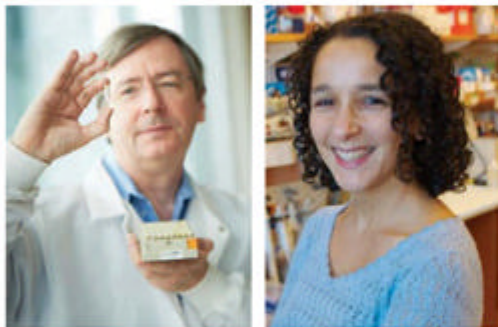
Application Requirements

- To be eligible for Graduate full-time opportunities, you should be in your final year of study or have less than three years of work experience.
- You must have a minimum Cumulative GPA (CGPA) of 3.20.
- Candidates for regular U.S. positions must be a U.S. citizen or national, an alien admitted as permanent resident, refugee, asylee, temporary resident, or an individual who possesses valid work authorization. Individuals with temporary visas (H-1, H-2, J-1, F-1, etc.) or who require sponsorship for work authorization now or in the future are not eligible for hire.

How to Apply

- In order to be considered for this position you must apply online at **www.shell.us/careers**.
- In the "Students and Graduates" section, click on "Shell Recruitment Day" and then create an account. When entering your contact details, select "Other" in response to "Where you found out about this Shell opportunity," click "Next" and then type in "Biodomain Researcher."
- We require a completed application, an updated copy of your résumé and an unofficial copy of your transcripts / grade report prior to be considered for an interview.

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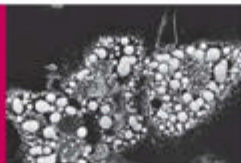
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At the Center for Childhood Cancer Research (CCCR) at The Children's Hospital of Philadelphia, we have over 85 affiliated scientists with 56,000 square feet of research space and access to one of the largest, highest-ranked clinical programs for pediatric cancer in the nation.

Our fully-integrated clinical, translational and basic science research program spans the entire spectrum of pediatric oncology. We sponsor a wide range of clinical trials, including a large and growing portfolio of investigational therapies for patients with refractory cancers. Our pioneering work in immunotherapy is making headlines — and there is so much more to come.

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Post-doctoral Fellowship on Mouse Models of Cancer

Washington University School of Medicine is one of the top five US medical schools and is a leader in cancer genome sequencing. By mining breast cancer genomics data, the laboratory of Dr. Ron Bose identified activating mutations in the HER2 Receptor Tyrosine Kinase (see Cancer Discovery, 3:224-37, Feb. 2013). Transgenic mice and Patient-derived Xenograft models allow us to test the role of HER2 activating mutations in several solid tumors, to study interaction with other oncogenes, and to determine drug sensitivity.

We are looking for an experienced animal researcher who can lead this effort. Requirements:

- 1) Experience in transgenic mice or cancer xenograft models.
- 2) Ph.D. in molecular biology, cancer biology or related disciplines.

Email your CV and a cover letter summarizing your research experience to Dr. Ron Bose, Division of Oncology.
rbose@dom.wustl.edu.

For further information: http://oncology.wustl.edu/people/faculty/Bose/Bose_Bio.html and <http://dbbs.wustl.edu/>

Technical/Research Assistants

The Koch Institute for Integrative Cancer Research, a National Cancer Institute (NCI)-designated Cancer Center, is a state-of-the-art cancer research facility as well as the hub of cancer research on the MIT campus. The Koch Institute (KI) brings together biologists and chemists along with biological, chemical, mechanical, and materials science engineers, computer scientists, clinicians and others, to bring fresh perspectives and an interdisciplinary approach to advancing the fight against cancer. This multi-faceted group of investigators is at the core of the Koch Institute's mission to develop new insights into cancer, as well as new tools and technologies to better treat, diagnose and prevent the disease.

The KI has several exciting Technical/Research Assistant positions open now and in the coming months. These positions are critical to our mission, supporting and enhancing cutting-edge, interdisciplinary, cancer-focused scientific/engineering projects. We are looking for individuals who value creativity, diversity, inclusion, and collaboration. Why not be part of a supportive community that fosters personal and professional development? Once you're here, you'll want to stay.

As a Technical Assistant, you will be part of a dynamic team and will provide technical expertise and support by: organizing and completing experiments and tests by studying project objectives and processes; documenting results; keeping project leader informed; maintaining equipment; maintaining a safe and healthy work environment; completing experiments and tests; performing protocols; updating job knowledge; exploring opportunities to add value to job accomplishments.

Minimum Qualifications: BS in Biological Sciences or other relevant field; hands-on experience in research laboratory environment; experience informing superiors and peers based on their information needs; committed to exceeding quality standards and providing exceptional services; exhibits meticulous attention to detail; committed to producing accurate and high-quality work; practiced documentation skills; uses multiple resources, quantitative, and qualitative research methodologies to capture and interpret information; aware of basic safety issues; follows safety procedures and maintains a safe work environment; trained in hands-on equipment maintenance.

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EDITOR'S PICK



UK health service is good value

From Jeremy Greenwood

The UK's National Health Service does cost more than it did when founded, but I dispute that this is the fundamental problem that Christopher Burke suggests (4 April, p 54). When it was founded, the UK was bankrupt after two world wars. Now we boast of being the sixth most healthy world economy.

We see attacks in the press claiming that the size of the NHS workforce is second only to China's People's Liberation Army. We don't see so much about the cost to the patient being among the lowest in the Western world and the quality of the service being among the highest. The potential costs to patients of an insurance-funded health service are fearsome.

I believe that perception of the problem of finance owes more to political ideology than to economics. In the meantime, practitioners are hampered by mushrooming systems of command and control. There is a gradual creep towards fee-per-item payment and treatment according to punitive protocols, all of which interfere with the practitioner getting on with the job.

As a general practitioner, I used to attend meetings about the nature of illness and how to treat it. Recently, virtually all my meetings have been about how to understand politically dictated targets and how to work them to minimise fall in income.

Bacup, Lancashire, UK

Belief, diversity and evolution

From Liz Bell

In his article on belief, Graham Lawton writes: "One of the most interesting things about belief is that it varies enormously from person to person, especially on issues that really matter such as politics and religion" (4 April, p28). My default "credulous brain" believes the premise that the formation of belief is an intuitive rather than a rational process and that deeply held, inflexible beliefs drive much conflict in the world.

It also strikes me that the enormous diversity of belief is a source of strength for our species, giving us flexibility, adaptability and options in coping with new challenges. The harm wreaked by fundamentalists and extremists is that they try to remove this diversity and impose uniformity, through moral imperatives, group interest and threatening violence towards dissidents.

I like to believe that by doing so they sow the seeds of the eventual destruction of the systems and societies they are trying to create, as they become unable to deal with new challenges that conflict with their rigid beliefs.

Great Sheffield, Berkshire, UK

From Don Ross

There is an evolutionary hypothesis for the strength of deeply held beliefs, outlined by Robert Trivers, who you have interviewed (8 October 2011, p 32). He thinks deceit is necessary for all living creatures in their quest for survival. As clever apes we find it impossible to deceive effectively unless we actually believe the lies we tell. We thus cannot rationally analyse these self-delusions. Just occasionally, however, when we retrospectively analyse some of our stupid behaviour, some hints of our own delusions may emerge.

Knowledge of this plausible explanation for irrational human behaviour has been comforting

for me, even if it is a delusion.
Vaucluse, New South Wales, Australia

From Peter Silverman

Lawton quotes psychologist Peter Halligan as saying: "The prime directive of the brain is to extract meaning. Everything else is a slave system." The purpose of the brain is rather to take in data, process it and make decisions – with the objective of maximising the chance of passing on the animal's genes.

Whether any meaning is or is not extracted in the process is a meaningless consideration.

Ruislip, Middlesex, UK

From Stephen Welch

In his fascinating look at belief, Lawton concentrates on the distinction between knowledge and belief. But the philosopher David Hume argues that we find actual knowledge only in maths and logic: everything else is belief, to which we ascribe probabilities based on our experience in the world. Such belief is obviously subjective, but it also becomes the basis of science via shared and repeatable experiments.

The distinction between belief and faith is more telling. We can believe in something when we have evidence for it. But faith is a belief in something without evidence, indeed often in the face of evidence.

Folkestone, Kent, UK

The humanities have truths, too

From Jonathan Goll

I disagree that "the scientific method... is still... the best way to distinguish what we believe from what we know" (4 April, p 5). The phrase "scientific method" tends to be used of study in which the data obtainable are quantifiable and have a high degree of certainty. Humanities researchers often try conscientiously to test

their theories against reality. Their "facts" may be uncertain and unquantifiable, but when taken together and pointing in the same direction may lead to conclusions with a high probability of being correct.

Economics is a warning. Perhaps struck by physics envy, many economists seem to have become ever more mathematical in their theories, but to have lost the desire to test their ideas against what has been actually happening. The result was a failure to see the credit crunch coming. They would have been wiser to stick to the methods of the humanities.

Birmingham, UK

Smart horse, expensive cart

From Bruce Denness

Researchers at the Children's Hospital Los Angeles wonder why parental income appears to influence the intelligence of their offspring (4 April, p 16). Surely this is putting the cart before the horse: as this trend tends to persist over many generations, it seems logical to suppose that intelligence leads to high income rather than the other way around.

Professions that require intelligence tend to be better rewarded than those that don't. Sport and entertainment may be exceptions. Would the income of sport and entertainment stars and their children's intelligence show the same relationship?

Whitwell, Isle of Wight, UK

Is there a learning speed limit?

From Richard Epworth

Emma Young's article on learning describes good learning practice (28 March, p 30). Yet we have little quantitative science about the process. There are two aspects of

Joe Singleton comments on Facebook about our Picture of the Day of super-typhoon Maysak

learning: absorbing novel information from the world, and introspection.

We can be forgiven for not understanding what goes on inside our heads, but there are scenarios where we can measure the rate of learning. There is surprising evidence that the maximum information rate of human learning is no more than a few tens of bits per second.

Sawbridgeworth, Hertfordshire, UK

Driven out of work when AI cars arrive

From David Gullen

So far the main problems raised about driverless cars have been technical, with social aspects mainly concerning the safety of passengers and pedestrians (14 February, p 20). But no one has discussed their impact on jobs.

Long-distance haulage, taxis, buses and coaches will no longer need human drivers. There are 92,000 registered black cab and private hire drivers in London alone, and an estimated 300,000

active drivers of large goods vehicles in the UK.

I expect that human-driven services will become a rarity – reserved for socially significant events like weddings and funerals and those who like to drive for pleasure; if, that is, human-drivable vehicles are still made, and are affordable.

Sutton, Surrey, UK

Atheism, axioms, positing and proof

From Ian Dunbar

Both Steven Miles (21 February, p 54) and Alan Webb (4 April, p 54) talk about “true scientists” not accepting an axiom without proof. But the definition of axiom in mathematics and logic is that it has no proof. Axioms are simply posited, and proofs of subsequent theorems are built on them.

The notion of proof belongs in mathematics and isn’t applicable to contingent matters such as the existence of god. Here we should look instead to the balance of evidence and to the requirement

to favour the null hypothesis until we have sufficient evidence to reject it.

Warrington, Cheshire, UK

From Keith Macpherson

When I say I am an atheist, those with any religious belief will imagine it is their god that I don’t subscribe to. But to quote Freddy Mercury, “I don’t believe in Peter Pan, Frankenstein or Superman”. I don’t believe in Zeus or Hera either. A believer in the Christian god who doesn’t believe in, say, Shiva, is an atheist to a Hindu. If you accept someone else’s belief in another god (this is called religious tolerance) then you are doubting your own belief – which makes you an agnostic.

Houston, Renfrewshire, UK

How does one shave a spider?

From Marilyn Smith

Please, please can you tell me how to shave a spider’s moustache (14 March, p 17)?

Upminster, Essex, UK

The editor writes:

■ In the experimental group, spiders were anaesthetised with carbon dioxide then their white “moustaches” were removed with a razor blade under a dissecting microscope. In the control group, the spiders were anaesthetised, but this time the researchers scraped their moustaches with the blunt side of the blade, so as not to damage them.

Tripping gaily over the Date Line

From Eric Kvaalen

You say the launch of a mission to the International Space Station mission would be “on Friday”, and in the next paragraph “on 28 March” (28 March, p 6).

Could it be that it was 28 March in Kazakhstan but still Friday in the US?

Les Essarts-le-Roi, France

The editor writes:

■ Yes.

For the record

■ California is not the largest of the United States, but the most populous (21 March, p 7). Apologies to Alaska.

■ We said electric cars emit “almost 20 per cent less heat” than petrol and diesel cars, when in fact they emit just under 20 per cent of the heat that conventional cars do – i.e. 80 per cent less (28 March, p 18).

■ Starting in September, all babies in the UK will be offered vaccinations against meningitis B (4 April, p 7). They remain at parents’ discretion.

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TOM GAULD





GOOGLE has obtained a US patent for personalities in robots. Kate Darling, a robot ethicist at the Massachusetts Institute of Technology complains in *IEEE Spectrum* that such patents are not good for robotics research because they may restrict innovation by other companies. Feedback's first thought is for the welfare of the robots. We recall the sufferings of Marvin the Paranoid Android, presented as a prototype of "genuine people personality" in *The Hitchhiker's Guide to the Galaxy* series by Douglas Adams.

CHECKING to see whether anyone was ahead of Google here, we found no trace of trademarks on "genuine people personality". We did, however, find that Federated Department Stores of Cincinnati, Ohio, held a US trademark from 1998 to 2000 on the slogan "be a person, not a personality". Before the Google announcement, this slogan was puzzling – which may

explain its abandonment. We would not be surprised if someone now tried to revive it.

TRADEMARKS are, to Feedback, a handy way to avoid the troublesome question "what exists?" by making a legal declaration that something does. Thinking of legal definitions of truth leads us to a court case in Taunton, Somerset, UK. Michael Overd, who is in the habit of preaching in the streets of Taunton, told the Christian Legal Centre he is "amazed" that a judge "sees it as his role to dictate which parts of the Bible can and can't be preached".

District Judge Shamim Ahmed Qureshi convicted Overd of a public-order offence for referring to the biblical proposition in *Leviticus* chapter 20, verse 13, that a man who "lieth with" another man "shall surely be put to death". His Honour helpfully suggested instead *Leviticus* 18:22, which merely states "thou shalt not do that. Somehow Feedback is less

alarmed by the judiciary ruling on such matters than by legislatures that attempt, for example, to make rules on the ratio of the diameter of a circle to its circumference...

THINKING of pi reminds us: how did you celebrate high-precision pi day (in US date format) on 3/14/15 9:26:54 (14 March)? Our phone alarm failed. Never mind, suggested readers from Australia and the US: why not a British celebration on 31/4/15 at 9:26:54? We won't name either, because of their small oversight: April hath 30 days. Tony Power's suggestion that "31 April" is 1 May will, we fear, work only for coders.

FRUSTRATED at missing pi day, we thought to explore the French Republican decimal calendar, and in particular year 31 of the third century of the revolution, month 4 (*Nivôse*), day 15. Each day was divided into 10 "hours" and each of these into 100 "minutes", so there will be another high-precision pi moment on the Revolutionary date 31/4/1 at 5:92.

There is some dispute about how this calendar would have handled leap years, had it not been suppressed in late 1805 (or rather *l'an XIV*) and revived only briefly during the Paris Commune uprising of 1871 (*l'an LXXIX, Floréal 16*, to be precise). But assuming that it would have done so sensibly, and using the handy calculator at stevemorse.org/jcal/french.html we find that pi moment will be some time after lunch on 21 December 2022 in our reactionary terms. Calculating the exact time makes our head hurt.

PAIN: this reminds us that a team at the University of Queensland in Brisbane, Australia, is studying persistent knee pain, and to this end is carrying out an "impact study". Mike Ford suspects it will find a direct relationship between impact and pain.

MEANWHILE, Aaron Berney proposes another date for your calendar. "Why not ditch the numerology nonsense?"

he asks. He proposes celebrating the day on which Earth "has travelled through one radian since the start of the year, and has therefore travelled approximately the distance from Earth to the sun." This falls on 28 February every year, he says, "shortly after 3am". That coincidental date leaves us worrying, though, that "radian day" may involve some messiness with leap years.

FINALLY, the inventive erudition of our readers knows few bounds. Pat Lueck responds to our feature on "Viking sunstones" (21 March, p 40), connecting it with research that won an Ig Nobel prize. This determined that dogs, when defecating or urinating, tend to align themselves north-south (27 September 2014).

Pat has dug out a snippet saying that according to the "Skansgaard documents" discovered in 1936 in



a Viking burial in England: "Eric, captain of the vessel, did he, in obedience to the traditions of sea-faring, start on his journey to the west... eying the sun as it traversed the sea... but... to ensure safe landings did he place a small dog in a large bowl of water thereby steering his craft on an assured path to the new lands..."

Now, if anyone can just help Pat and ourselves with the source of this wondrous quotation...

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Peter Duffell sends a sign from a shop window opposite Nottingham Castle advertising a "Christian Duplicating Service". He, too, had always wondered how the faithful reproduced...

Cloud cover

How much data does the World Wide Web hold?

■ Whatever the amount is in any one moment, it'll be quite a bit more in the next. A good estimate floating around is 1 yottabyte, or a trillion terabytes. Yet this figure is now almost a year old and, because the web is widely described as growing exponentially, it is reasonable to assume it could now have doubled to 2 or more yottabytes.

We should also consider the so-called deep web, which encompasses anything that is not found by a mainstream search engine. This includes many large databases for travel bookings, merchandise data for online shopping, any social media networks that do not put everything in the public domain, and so forth. Figures suggest that 80 per cent of the web is dark, so if that is true, the web comprised 5 yottabytes of data in 2014 and could now hold double that or even more.

It's also important to add that many websites do not reveal how much data they store. Hosting sites hold several redundant copies of almost everything, in multiple locations on varying types of media. Should we count this as part of the web?

Similarly, much of the information on the web is duplicated. Years ago, I searched for a list of jokes and found a dozen copies of the same list with

only minor differences, because every revised version was put on a new site and page. Who can guess how many copies of popular content exist?

It's big, that's for sure.

*David Morton
Geeveston, Tasmania, Australia*

Supply chains

It is fairly common for numbness to develop in an arm in which the blood supply has been temporarily shut off by lying in an awkward position. We notice when a limb goes numb and restore sensation by moving it, but could this also happen to an internal organ, and what would we feel if so?

■ Numbness in an arm is not caused by shutting off the blood supply. It is very difficult to compress an artery sufficiently to cut off all flow, short of applying a tourniquet. Complete obstruction of an artery, such as a clot in the femoral artery (to the leg) results in severe pain, not numbness. The numbness in the arm is due to pressure on the blood supply to a nerve.

The skin of the arm is supplied by skeletal nerves that transmit sensations such as pressure, touch, temperature and pain. Internal organs are not supplied by skeletal nerves; you cannot feel your heartbeat from inside your chest, your lungs moving against the inner chest wall or your guts sliding around in your abdomen. The linings of the chest and abdomen walls are supplied

by skeletal nerves, but only with pain fibres – so you can feel the pain of pleurisy or peritonitis.

Internal organs are supplied by the autonomic nervous system, principally the vagus nerve. This allows you to feel the unfocused pain of a heart attack and of colic, but no more than that. There was once a fashion for surgical division of the vagus nerve to treat peptic ulcer. This upset gut motility but did not lead to any obvious disturbance of sensation.

*David Wheeler
Dalston, Carlisle, UK*

■ The arm numbness is caused by inadequate blood supply to peripheral nerves. The affected muscles are also paralysed. As circulation is restored, the nerves

“The heart can be deprived of oxygen if the blood supply is compromised and the pain is called angina”

recover and the strange feeling generally referred to as pins and needles occurs.

The heart muscle can be deprived of oxygen if its own blood supply is compromised. This causes pain known as angina, which is felt in the middle of the chest and which radiates down the left arm. Sometimes the pain is only felt in the second rib interspace on the left.

When we exercise, our heart rate increases to provide sufficient blood and therefore sufficient oxygen to the exercising muscles. A person

who exercises regularly but who has a compromised blood supply will experience angina that disappears with rest, in contrast to the pins and needles of a recovering peripheral nerve.

*Hilton Selvey
Mooloolah, Queensland, Australia*

■ I work as a nurse in an operating theatre recovery room, and have seen this in internal organs. Sometimes people come through operating theatres having presented with perhaps a week's history of acute abdominal pain. They have often walked into hospital.

When a laparoscopy is performed, their whole bowel can be found to be gangrenous, the smell of which is indescribable. Sadly, all that can be done is to sew them up and, if they wake from the anaesthetic, gently tell them they probably have only hours to live. This condition is usually caused by a clot blocking blood flow to the bowel.

*Ray Thompson
Worthing, West Sussex, UK*

This week's question

DIG UP THE TRUTH

We noticed a huge number of molehills when walking through fields and woods on the Thames Path in Oxfordshire recently. Most were on or near the path, rather than out in the fields. Why is this?

*Catherine Kennally
London, UK*

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